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PRELIMINARY PERFORMANCE AND INTERFACE SPECIFICATION GROUND OPERATIONAL SUPPORT SYSTEM PROJECT APOLLO SPACECRAFT

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1.0 SCOPE AND DEFINITIONS

1.1 Scope. - This specification describes the preliminary performance requirements of the Ground Operational Support System (GOSS) for the Project Apollo Spacecraft. The specification identifies the required stations and facilities, and establishes requirements for the integration of all network elements and their functional relationship. This specification also defines the interface requirements between the GOSS network and all other system elements. SID 62-77 lists and provides specifications for equipments required at each of the GOSS stations or facilities.

1.2 Project Apollo Description. - The purpose of Project Apollo is to develop the technology of manned space flight to a level permitting manned flight to the moon, landing, conducting lunar explorations, and returning safely to earth. The Apollo spacecraft shall be designed to achieve this ultimate capability. The objectives of the various missions are planned to overlap. Each mission will provide for the qualification of systems so as to best achieve the objectives of subsequent missions.

1.2.1 Earth-Orbital Missions. - Earth orbital missions shall be limited to manned, low altitude, earth orbital flights of up to two weeks duration. The objectives of these flights shall include the qualification of systems to be used in subsequent mission phases; studies of the physiological and psychological reactions and capabilities of the spacecraft crew under conditions of extended periods in the spacecraft environment; development of flight and ground operational techniques and equipment for space flights of extended periods; and experimental investigations to acquire information for the lunar missions.

1.2.2 Lunar Missions. - These missions shall consist of circumlunar and lunar-orbital flights to further develop and operationally test the space vehicle. Close-up reconnaissance of the lunar surface shall be made to determine possible landing areas, conduct scientific investigations, and investigate and confirm capabilities of optical and other sensors.

1.2.3 Lunar-Landing Mission. - This mission shall be a manned lunar landing for limited observation and exploration in the landing area, and subsequent safe return to earth.

1.3 Mission Phases. - The Apollo flight phases are defined for the earth orbital and the lunar missions. Flight phases common to more than one mission are not repeated.

1.3.1 Earth Orbital Mission. -

1.3.1.1 Ascent. - Ascent begins with launch vehicle liftoff and ends upon earth orbit injection. The ascent phase is common to all phases and includes: 1st Stage Boost, 1st Stage Separation, and 2nd Stage Boost Into Earth Orbit.

1.3.1.2 Earth Orbit. - Earth orbit begins at the termination of second stage burning and ends at the initiation of the orbit ejection phase. The earth orbit phase includes the separation of the Apollo Spacecraft from the launch vehicle and all spacecraft attitude control maneuvers.

1.3.1.3 Hohmann Transfer. - The Hohmann transfer refers to an optional phase that may be used to change the orbital altitude. It utilizes the Service Module propulsion.

1.3.1.4 Orbit Ejection. - Orbit ejection defines the retro powered flight phase required to place the spacecraft on a de-orbit coast trajectory.

1.3.1.5 De-Orbit Coast. - The de-orbit coast phase follows orbit ejection, continues through the vacuum descent from orbit and terminates at the entry interface. The Command Module is separated from the Service Module and is oriented for entry during this phase.

1.3.1.6 Entry. - The entry phase begins at the entry interface (400,000 feet) and ends at the recovery interface altitude (100,000 feet). The entry phase includes a pull-up to horizontal flight, a transition from pull-up to glide, and a glide to the recovery interface. The entry phase is common to all missions.

1.3.1.7 Recovery. - The recovery phase begins at the recovery interface (100,000 feet) and ends at touchdown. The recovery phase includes a glide to drogue chute deployment, drogue chute deployment and descent, and main chute deployment and descent. The recovery phase is common to all missions.

1.3.2 Circumlunar Mission. -

1.3.2.1 Earth Orbit. - The earth orbit phase is used to place the spacecraft in the inertial position required for translunar injection. Included in this phase are the second stage separation and coast attitude control. This phase is common to all lunar missions.

1.3.2.2 Translunar Injection. - The translunar injection phase begins at the start of the firing sequence of the Launch Vehicle final stage and terminates at launch vehicle engine shutdown. The velocity vector at shutdown will provide a free return circumlunar trajectory. Included in this phase are the firing sequence prior to engine ignition, and the Launch Vehicle final stage boost. This phase is common to all lunar missions.

1.3.2.3 Translunar Coast. - The translunar coast phase begins at engine shutdown and terminates at perilune. This phase includes the separation of the Launch Vehicle from the Spacecraft, mid-course velocity corrections (provided by the Service Propulsion System), and attitude control maneuvers. This phase is common to all lunar missions.

1.3.2.4 Transearth Coast. - The transearth coast phase commences at perilune for the circumlunar mission and at transearth injection for the lunar orbit and the lunar landing mission, and terminates at earth entry. This phase includes the mid-course velocity corrections required of the Service Propulsion System, attitude control maneuvers, separation of the Command Module from the Service Module after the final mid-course velocity correction, and orientation of the Command Module for entry. The transearth coast phase is common to all lunar missions.

1.3.3 Lunar Orbit Mission. -

1.3.3.1 Lunar Orbit Injection. - The lunar orbit injection phase is a retro power phase initiated at perilune to reduce the hyperbolic approach velocity to a lunar orbital velocity. This phase includes the firing sequence, and powered flight, and is common to both the lunar orbit and landing missions.

1.3.3.2 Lunar Orbit. - The lunar orbit phase begins with lunar orbit injection for the earth orbital and lunar landing missions. In the case of the landing mission it also follows the lunar ascent phase. The lunar orbit is used for lunar surveillance and for positioning of the spacecraft for lunar landing or transearth injection. Specifically the orbits used for the landing "approach orbit" and "departure orbit" respectively. This phase includes all attitude control maneuvers and is common to both the lunar orbit and lunar landing missions.

1.3.3.3 Transearth Injection. - The transearth injection phase follows the lunar orbit phase. The purpose is to provide the velocity vector at shutdown required to satisfy entry constraints.

1.3.4 Lunar Landing Mission. -

1.3.4.1 Hohmann Transfer. - The Hohmann transfer is a short retro powered phase from circular lunar orbit, utilizing the Landing Module Propulsion system, and is followed by a coasting 180° descent, to place the spacecraft in position for a lunar landing approach. For lunar orbit missions, this transfer may be used for lunar surveillance using the Service Module propulsion. In this case the spacecraft shall be allowed to return to its original altitude prior to re-establishing a circular orbit. This phase includes the firing sequence prior to engine ignition and attitude control maneuvers during coasting flight.

1.3.4.2 Main Retro. - The main retro phase starts at perilune of the Hohmann transfer and terminates at 1,000 ft. above the lunar surface. The Landing Module propulsion system is used to slow the spacecraft to almost zero velocity while steering it to a position approximately 1,000 ft. above the landing site. This phase includes the firing sequence prior to engine ignition.

1.3.4.3 Lunar Landing. - The landing phase commences at approximately 1,000 ft. and terminates at lunar touchdown. It includes hover, site selection, translation, and touchdown, using the landing module propulsion system.

1.3.4.4 Lunar Ascent. - The lunar ascent phase begins at lunar liftoff and terminates at injection into lunar orbit, using the service propulsion system.

1.4 Space Vehicle Definitions. -

1.4.1 Apollo Launch Vehicle. - The Saturn C-1 launch vehicle shall be the basic launch vehicle for Apollo earth orbital missions. The advanced Saturn C-5 launch vehicle is expected to be the launch vehicle for the circumlunar and lunar orbital missions. The Nova type launch vehicle and the Saturn C-5 launch vehicle are both being considered for the lunar landing mission. Other launch vehicles may be required for certain developmental and qualification flights.

1.4.2 Spacecraft. - The spacecraft that will be utilized, where a direct ascent from earth or an earth orbital rendezvous, and a direct lunar landing technique are used, consists of the following modules: Command Module, Service Module II, Lunar Braking Module, and Service Module I.

1.4.2.1 Command Module. - The spacecraft shall include a recoverable Command Module which shall remain essentially unchanged for all Apollo missions. The Command Module shall be the space vehicle command center, where all crew-initiated control functions are exercised. As the command center, this module shall contain the communication, navigation, guidance, control, computing, and display equipments, required for selection of operating modes by the crew. This module shall include features which allow effective crew performance, such as windows with a broad field of view for general observations, landing, and rendezvous; and also equipment arrangements allowing access for maintenance.

1.4.2.2 Service Module II. - The spacecraft will include an unmanned Service Module for all missions except super-orbital reentry tests. This unmanned module shall contain stores and systems which do not require crew access for operation or maintenance and which are not required by the Command Module after separation from the Service Module II. The Service Module II will contain the propulsion requirements for the lunar takeoff, transearth injection, and transearth midcourse correction maneuvers. This module will be jettisoned prior to earth reentry and shall not be recoverable.

1.4.2.3 Lunar Braking Module. - The spacecraft will include a Lunar Braking Module which shall be utilized to provide translunar midcourse correction, retro into lunar orbit, and a Hohmann transfer to within 2,000 ft. of the lunar surface. At this altitude this module will be jettisoned.

1.4.2.4 Service Module I. - The spacecraft will include a Service Module I which shall be utilized as the lunar touchdown module. This module shall also provide a base from which the Command and Service Module II may be launched from the lunar surface.

2. APPLICABLE DOCUMENTS. - The following documents form a part of this specification and are applicable to the extent specified herein.

2.1 Government Documents. -

Specifications

Military

MIL-M-26512B	Maintainability Requirements for Weapon Support, Command and Control Systems and Equipment dated 3 March 1962

MIL-R-27542 and Ammendment I	"Reliability Program Requirements for Aerospace System, Subsystem and Equipments" dated 28 June 1960 and 31 October 1961 respectively.

2.2 Non-Government Documents. -

North American Aviation, Inc.
Space and Information Systems Division (NAA/SID)

SID62-77	Preliminary Performance and Interface Specification, Ground Operational Support System (GOSS) Equipment
SID62-57	Apollo GSE Performance and Interface Specification
SID62-86	Preliminary Performance Specification Communications and Instrumentation Subsystem Project Apollo Spacecraft NAS9-150
SID62-91	Preliminary Specification, Apollo Systems Monitoring, Personnel Performance
SID62-162	Apollo Training Plan for Phase A
SID62-223	Preliminary Apollo Program Plan

2.3 Reference Documents. -

AP-3A	Ground Environment for the Apollo Mission (MIT Report)
WDL-TR-E118	Proposed GOSS Communication Control Techniques for Manned Space Flight Programs (Philco)
WDL-TR-E113	Monthly Progress Report Number 1 on Study, Design, and Development Contract for Manned Space Flight Operations Control and Support (Philco)
WDL-TR-115	Monthly Progress Report Number 2 on Study, Design, and Development Contract for Manned Space Flight Operations Control and Support (Philco)

3.0 REQUIREMENTS

This section summarizes the performance requirements for the Apollo Ground Operational Support System (GOSS). The requirements are based on the following assumptions:

a. Utilization of the existing Atlantic Missile Range (AMR) for the ascent phases of Apollo missions

b. Utilization of existing Mercury stations for near-earth (orbital) coverage whenever feasible

c. Utilization of the three DSIF stations for lunar-distance tracking and telecommunications

d. Utilization of existing and programmed ground communications between stations of the GOSS

e. A Mission Control Center (MCC) at Houston for centralized control of the GOSS

f. A Launch Control Center (LCC) at Cape Canaveral, Florida

g. A Central Computer Complex at Houston, Texas

h. A Communications Center at Houston, Texas

i. A Recovery Control Center at Houston, Texas

3.1 General Requirements

3.1.1 GOSS Functions. - The purpose of the GOSS is to support the spacecraft and spacecraft crew in all ways necessary to provide maximum assurance of mission accomplishment and maximum crew safety for each Apollo mission. The basic GOSS functions are defined as follows:

a. Spacecraft support

b. Mission evaluation

c. Public information

3.1.1.1 Spacecraft Support

3.1.1.1.1 Monitoring. - The GOSS shall support the spacecraft crew by monitoring mission progress. There are three aspects to this function.

a. During the pre-launch and boost phases, the GOSS will receive, evaluate, and act upon data, some of which is not available to the spacecraft.

b. During all other phases of missions, the GOSS will provide alternative monitoring and interpretation of telemeter data relating to status and performance of onboard instruments and systems.

c. In all phases of missions, the GOSS will determine the spacecraft trajectory based upon radar tracking data (independent of spacecraft collected data), and use this data to verify spacecraft generated information and support the spacecraft as needed in emergencies.

3.1.1.1.2 Diagnosis. - The GOSS will provide backup diagnostic capabilities for assisting the spacecraft crew in checking performance of the spacecraft systems, recognizing failures or potential failures, locating points of failure, and suggesting actions for preventing or remedying failures. The GOSS can use more manpower, data, and equipment than are available in the spacecraft, and can perform faster and more accurate computations when necessary in connection with contingency situations.

Contingency situations of the following types may require diagnostic support by GOSS:

a. Crew sickness or cabin environmental factors which result in degraded crew performance capability. The occurrences of these conditions will ordinarily be monitored and detected by the crew. Consulting and diagnostic assistance will be provided from the ground, as required.

b. Spacecraft systems malfunctions. These are tentatively grouped as follows:

1. Excessive vibration or noise (during powered flight), which can reduce the system reliability or cause failures.

2. Environmental control system malfunctions, including leaking oxygen lines, inability to maintain cabin pressure or temperature, etc.

3. Sensor system malfunctions, resulting in the indication of malfunctions which in fact do not exist. Such malfunctions may be displayed on the ground, but not in the spacecraft, or vice versa. In some cases, both the ground and spacecraft monitoring equipment may indicate a non-existent malfunction. The GOSS must be capable of distinguishing between a true and an indicated malfunction.

4. Power and electrical system malfunctions

5. Guidance and control system malfunctions, including attitude control, propellant utilization, attitude reference, etc.

6. Communications malfunctions, including voice, telemetry radio transponders, and radio recovery aids.

The GOSS will assist the spacecraft crew by using the available telemetered and supplemental voice data in conjunction with its own resources, to investigate possible causes of the malfunctions and through direct voice conversation assist in isolating the cause. The MCC will have the reliability history for all systems and will have a capability for simulating spacecraft systems operations and quickly isolating the more likely causes of malfunctions.

3.1.1.1.3 Spacecraft Systems Backup. - The GOSS will provide backup to certain spacecraft systems as required. The principal system for which backup is planned is the navigation and guidance system.

3.1.1.1.4 Mission Capability. - The GOSS will provide evaluations of mission and alternate missions performance capability. This will include making decisions and computing trajectory parameters for alternative missions when required. Decisions will be based on information obtained from on-board instrumentation and GOSS. As an example of a requirement for this function, the crew can ascertain how much fuel remains, but may not be able to compute how long it will last. In-flight trajectory errors, and other operational type errors may result from miscalculations, errors in reading displays, insufficient precision in calculations of headings, thrust cut-off times, etc. The ground system will continually maintain an accurate estimate of spacecraft position and velocity, and of deviations between the planned or predicted and the actual values, and will advise the spacecraft commander whenever significant deviations occur. Space environmental hazards, such as changes in solar weather and the Van Allen radiation belts, meteorite showers, and meteors may be detected on the ground and can result in altering or aborting the mission.

3.1.1.1.5 Weather Information. - The GOSS shall provide the spacecraft crew with information on surface weather at primary, backup, and alternate landing sites, on high altitude weather for determining reentry path perturbations due to variations in atmospheric density, and on solar weather for flare prediction and changes in the Van Allen belts.

3.1.1.2 Mission Evaluation. - The GOSS shall receive and record spacecraft systems, trajectory, and operational data for post-flight analysis and evaluation of equipment performance, personnel, and operational procedure. Included will be the review and corroboration of crew reports and recommendations for corrective actions where indicated.

3.1.1.3 Public Information. - The GOSS, through the MCC, shall provide the public with information concerning flight progress and crew status.

3.1.2 Operational Concept. - The GOSS shall consist of the following principal subsystems:

a. Mission Control Center (MCC)

b. Launch Control Center (LCC)

c. Remote Station Network

d. Recovery Centers

The interconnection and breakdown of each of these subsystems is shown in Figure 1. These subsystems are discussed in detail in later sections. The remote stations will include all stations providing tracking and communications support for the earth orbital or lunar missions, or facilities to assist the spacecraft during landing and recovery. The GOSS network shall operate on a centralized control basis. The overall control of the Apollo GOSS shall be accomplished from an MCC located at Houston, Texas. Operational control shall be delegated to the LCC located in the Vertical Assembly Building during the pre-launch and launch phases of the Mission to lift-off. Operational control for the boost and orbit injection phases will normally revert to the MCC after lift-off. In the event of communications failure, the LCC shall be capable of directing the mission through injection. Operational control may also be delegated to any remote station or recovery center at the discretion of the MCC. The blockhouse at complexes 34 or 37 shall serve as the LCC when required.

For all missions the GOSS shall provide, to the extent practicable, continuous surveillance and monitoring of the spacecraft flight progress, on-board systems, and crew status. In the event of an emergency in the

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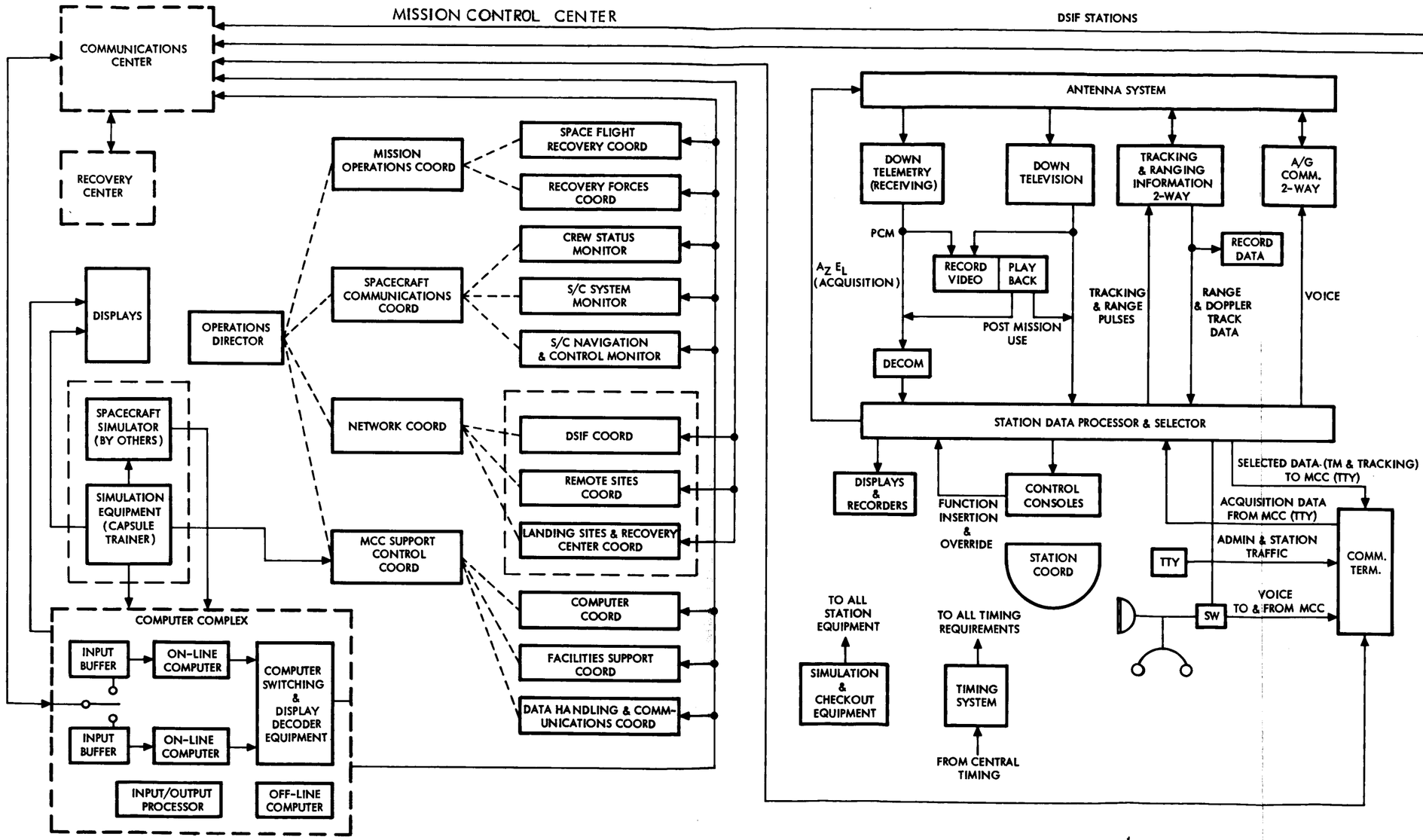

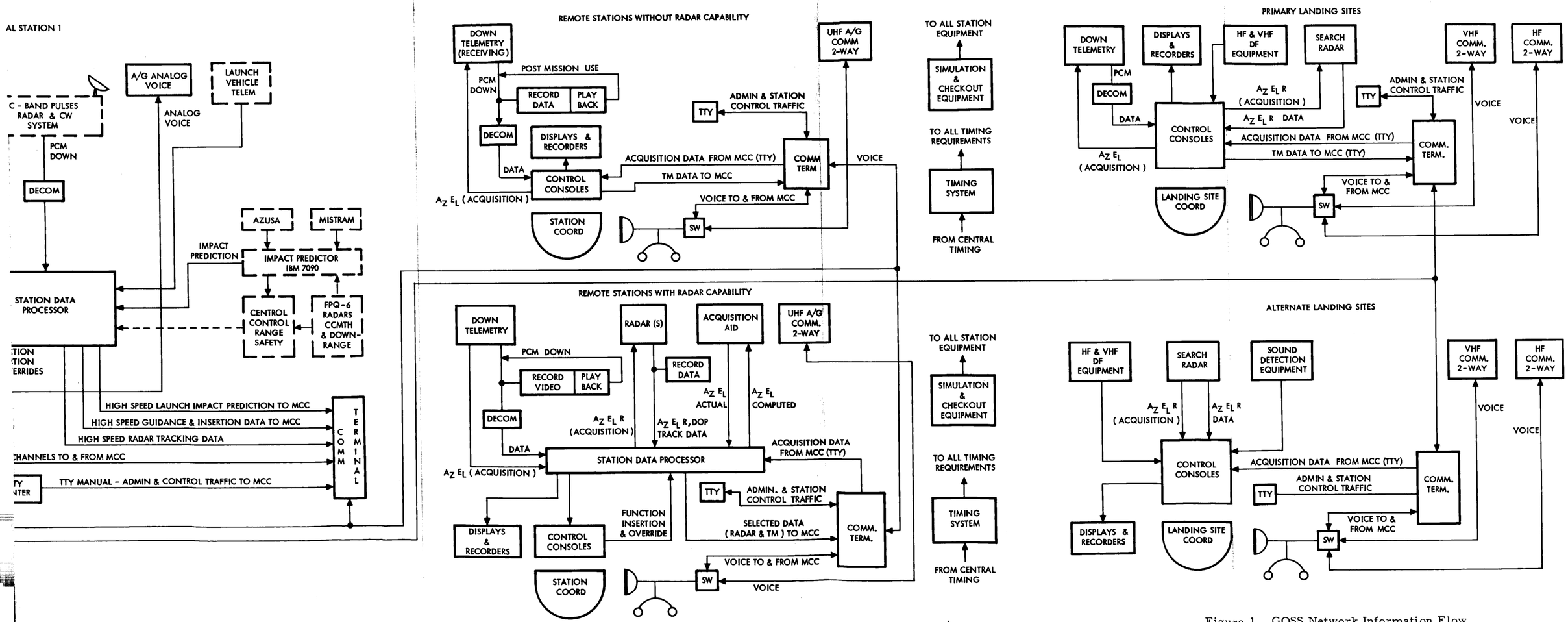

Figure 1. GOSS Network Information Flow

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spacecraft, the GOSS network station shall transmit emergency data to the MCC as soon as possible for their information and use in making decisions. The GOSS shall also provide for the transfer of certain MCC information to the spacecraft. The alternate (or emergency) landing stations shall be capable of assuming operational responsibility for emergency landings and recoveries.

3.1.2.1 Mission Control Center (MCC). - The MCC is regarded as a central complex which includes and directs several major support facilities. The MCC shall monitor the spacecraft and direct the support elements for all phases of the earth orbital and lunar missions. The MCC complex shall include a computer center, a communications center, a remote station and a recovery control center. The MCC complex shall also include facilities for training astronauts, flight controller and ground crew personnel, for mission simulation and the development of operational procedures. These training and simulation facilities, including a remote station simulator and the Apollo crew trainer shall be capable of individual or joint usage, or of being coupled with MCC for integrated exercises as required.

The MCC shall prescribe alternate modes of operation when required by less than optimum performance of any Apollo mission support system. A limited control capability may be delegated by the MCC to other stations of the GOSS as required. The MCC shall conduct GOSS checkout and verification before and during the missions. It will make decisions regarding the time of launch when the supporting information is inconclusive or probabilistic, and when mission-oriented, public opinion or national interest factors must be considered. The MCC shall provide necessary data in support of the mission to any remote station and to the recovery force.

The computer complex shall provide the data processing and computing functions required for control of the GOSS network and support of the spacecraft. Computer support shall be provided for mission planning, system exercising and checkout, personnel training, updating spacecraft, trajectory and other displays, in-flight operational decisions, and post-flight analyses. The functions will also include those required to support the spacecraft navigation and guidance systems.

The communication center shall provide for the switching, recording and temporary storage of all or part of the communications between the MCC and the LCC, remote stations, and recovery forces; and between the operations control, computer complex recovery center, and crew trainer. The communications center will also provide status displays of all communications routes within GOSS and of the selection of communications modes. Communications status will be presented to the MCC communications controller by voice or by an indicator, as required.

The Recovery Control Center (RCC) shall provide the Operations Director with the status of all recovery forces, and be prepared to recommend landing sites on the basis of recovery force status and weather conditions at the various landing sites. The RCC shall inform the recovery force as to mission status, expected re-entry and landing points and spacecraft condition. Under the strategic command of MCC, the recovery forces will exercise tactical control of their own forces.

3.1.2.2 Launch Control Center (LCC). - The LCC will be located in the Vertical Assembly Building at Cape Canaveral. The LCC shall be responsible for space vehicle preparation and checkout, conduct the mission countdown, and the monitoring of booster parameters during the launch, ascent and powered phases of flight. The LCC will monitor and analyze booster data and make abort decisions on the pad in the event of critical booster system malfunction. The AMR range safety function will be located at the LCC.

The LCC shall be equipped to function as a remote station. The design shall be such that normal remote station operation may be concurrent with other LCC operations. The spacecraft trajectory and systems status data shall be summarized and relayed to the MCC during the ascent and injection phases, and at other periods when the spacecraft is within the tracking and communications coverage of the Cape Canaveral Remote Station. The MCC will monitor the trajectory and system status during the launch and powered flight phase and shall make the decision to abort when the potential abort is a trajectory deviation which does not affect range safety.

3.1.2.2.1 Operational Scope of Range Safety Officer (AMR). - Range Safety control contributes to:

a. The acceptance of a lift-off time, based on all range safety requirements being met, e.g., pad cleared, and no unauthorized vessels in anticipated emergency landing areas, etc.

b. The acceptance of the initial phases of powered flight based on range limits and booster impact prediction safety requirements.

Both of these activities are under the sole control of the Range Safety Officer, and his decision to delay launch time, or abort or destruct a flight is irrevocable. This control terminates when the vehicle has established a dynamic condition where it cannot infringe on the prevailing safety requirements.

3.1.2.3 Remote Stations. - The remote stations, consisting of land and ship stations, provide capabilities for tracking the spacecraft, maintaining voice communications with the spacecraft, receiving telemetry data, and

monitoring and summarizing telemetry and tracking data for relay to the MCC. Certain remote stations shall be capable of providing tracking and communications support for the spacecraft during lunar missions. Certain remote stations shall be capable of supporting re-entry and landing operations.

The remote stations may have tracking radars, acquisition aids, telemetry receivers, data processors and communications terminals. Equipments will be provided at individual stations in accordance with their specific functions. The communications terminal will control the flow of information through the station. An automatic data processor will provide for decommutation of telemetry data, editing and coding of information for teletype or voice transmission to the MCC, and other computational support for remote station functions. Remote stations used for tracking and communications during lunar mission phases will have additional data processing and display equipments allowing a back-up control of the mission, if warranted by ground communications difficulties. These stations will also have back-up tracking radars, or additional stations should be provided.

A remote station shall be located in the vicinity of Houston. This station shall provide: real or simulated inputs to the MCC for mission simulation, crew and ground operating personnel training, development and improvement of network operational procedures, network validation, and spacecraft-GOSS equipment compatibility checks.

3.1.2.4 Recovery Centers.- The requirements for the central Recovery Control Center (RCC) and for additional alternate recovery centers are as follows:

a. A central RCC shall be established within the MCC complex at Houston.

b. In the event of contingency landings, the nearest GOSS station, under the direction of the central RCC, shall function as an alternate RCC, until the recovery force is in position.

c. The MCC will exercise strategic control of recovery forces through the Recovery Control Center. Tactical control of recovery forces will remain with local task force commanders.

d. The remote GOSS station which provides tracking coverage of the Spacecraft during reentry at any of the planned alternate landing sites shall be equipped and trained to function as an alternate RCC, until the recovery force is in position.

e. Communications links and operational procedures shall be designed to support this capability, and the procedures shall be proven during simulation exercises.

f. The inherent communication coverage and capabilities of a DOD recovery force, coupled with those of the GOSS network, make this plan economically sound and tactically feasible. It permits maximum use of existing facilities, minimum new requirements, and close coordination with the MCC during all phases of recovery.

3.1.2.5 Operational Plan. - The GOSS activities shall be considered in two groups; those associated with conduct of the flights, and those auxiliary activities associated with systems and equipment verifications, training, development of operational procedures, and post-flight analyses.

3.1.2.5.1 Flight Activities

3.1.2.5.1.1 Pre-Flight. - The MCC shall direct the entire mission, conduct the GOSS checkout and flight simulation. It will control the countdown, evaluate weather, monitor recovery status, spacecraft-booster status and capabilities, and make all final decisions concerning delay and postponement.

The MCC will delegate to LCC the preparation and checkout of the spacecraft-booster combination, the conduct of the countdown and the launch. Control of the countdown shall revert to MCC at lift-off, but operational procedures will be so designed that LCC can retain control through the powered phase of flight if so directed by the MCC. To provide the most rapid response in the event of booster malfunction, pad abort responsibility will be delegated to the LCC or the Spacecraft crew as required.

3.1.2.5.1.2 Ascent Phase. - Control of the flight shall revert to MCC at lift-off. Key booster parameters will be relayed to the MCC for analysis and decision.

The LCC will continue to monitor the detailed booster data, utilizing personnel experienced with booster systems and performance. Operational procedures and previous simulations shall reflect the capability of LCC to assume control at any time as directed by the MCC.

Booster data will be transmitted to the MCC (Computer Complex) in a wide band data link for computation, display, analysis and decision. Processed booster position data, including trajectory, velocities and deviation from planned path will be displayed at MCC and LCC.

The data selection system shall be flexible such that the LCC may take full advantage of Cape Canaveral raw radar data or of booster guidance computer data as a back-up function to the MCC. Provision shall also be made to transmit such data to MCC for comparison and analysis.

Booster performance data as determined from telemetering links will be presented in detail at LCC, and key parameters will be transmitted to MCC.

Spacecraft sub-system data, as determined from telemetering links, will be presented at MCC and LCC until loss of signal at Cape Canaveral; a limited number of parameters will be presented at the MCC via the Bermuda wide band data link until loss of signal at Bermuda.

3.1.2.5.1.3 Orbital Flight. - The MCC will provide operational instructions and acquisition data to the remote stations, and support and backup information to the spacecraft. Support of the spacecraft will include assistance in diagnosing causes of, and remedying, spacecraft systems malfunctions. This function will be provided, when appropriate, by use of systems specialists, recall of telemetered data, and analyses of trends. Real time voice, telemetry, and tracking data received at the remote stations will be edited and relayed to the MCC.

The responsibility for performing ground support functions will be transferred to a remote station, by prearrangement in the event of a communications failure, or by directive in case of a lack of real time ground communications.

3.1.2.5.1.4 Lunar Injection.- If feasible, continuous tracking and communication coverage will be provided during and immediately following injection from an earth orbit to a lunar transfer trajectory. The normal systems data will be summarized and relayed to the MCC. Booster data will also be monitored at the remote stations. Acquisition data for the remote stations will be computed at MCC and relayed to the stations involved in the tracking operation. These may be near-earth land or ship stations with C-band radar or they may be fixed or transportable DSIF stations, or any combination of all of these, depending on injection point location. Each tracking system will use its established communication system for maintaining contact with the MCC.

The spacecraft crew will be responsible for abort decisions.

3.1.2.5.1.5 Lunar Missions Phases.- The MCC will control the GOSS for all phases of lunar missions, from lunar injection to reentry. The primary responsibility for providing guidance and navigation backup, and assistance in diagnosis, shall be at the MCC. However, some functions may be delegated to the DSIF stations in the event of limited point to point communications. Each DSIF station may provide limited computations for backup of the spacecraft navigation and guidance system, and a limited capability for assisting in diagnosing spacecraft systems malfunctions.

3.1.2.5.1.6 Reentry and Recovery.- The MCC shall control the GOSS during spacecraft reentry and recovery. The MCC will normally provide

acquisition data to the remote stations; touchdown time, expected landing point, and crew condition to the recovery forces; and will exercise strategic control of the recovery forces. The recovery forces will exercise tactical control of their own operations.

3.1.2.5.1.7 Post Flight.- The MCC will conduct the debriefing of the GOSS.

3.1.2.5.2 Auxiliary GOSS Activities

The MCC and appropriate portions of the GOSS remote stations and of the communications network will be used in preparing for flight missions and in conducting various analyses related to the missions.

3.1.2.5.2.1 Pre-flight Planning.- The MCC computers will be used to provide computations and data processing in support of studies, analyses, program preparation, and data reduction.

3.1.2.5.2.2 Personnel Training and Exercising.- Extensive training and simulation exercises shall precede each Apollo mission. Such exercises shall include the MCC, LCC and all remote GOSS stations, and shall meet the following criteria.

a. The exercises shall include the alignment and calibration of individual equipments throughout the entire GOSS.

b. Simulation equipment shall provide for the introduction of signals to all equipments, sub-systems and systems of the entire GOSS.

c. The Apollo missions will be simulated first at the station and outer level, followed by an integrated mission simulation involving the entire GOSS network.

d. Simulations will include the loss of critical GOSS support systems, communication links and entire stations.

e. Simulations will include the presentation of S/C sub-system data on all displays indicating both normal and abnormal operation, and simulating degradation and malfunction of S/C equipments. They shall be realistic in content, requiring decisions and recommendations from Flight Controller and MCC personnel during any or all phases of flight.

f. Proficiency will be maintained between Apollo missions through training devices and methods now under study.

3.1.2.5.2.3 Procedures Development.- The MCC, crew trainer, and Houston remote station will be used to develop operational procedures.

3.1.2.5.2.4 Equipment Verification and Modification.- The MCC, LCC, remote stations, and crew trainer will be used individually or in combination to validate the equipment and develop modifications to the equipment.

3.1.2.5.2.5 Recovery Training and Development.- The operational training of RCC personnel will be concurrent with that of Flight Crew and Flight Controller personnel: simulations and exercises will be designed to include permanent RCC personnel. Training of Recovery Forces is outside the intent of this specification.

3.1.2.5.2.6 Post Flight Evaluation and Analysis.- The MCC will perform post flight evaluations and analyses of each mission.

3.1.3 Information Flow Requirements

The term "information flow" includes all aspects of communications between the spacecraft and the ground; between ground stations; among personnel in the support system complex; and all data gathering, editing, distribution, interpretation, and processing pertinent to the mission accomplishment. The requirements shall be based upon a thorough, critical analysis of all Apollo missions, including the research and development flights; and shall consider all mission phases and phase transitions, and all reasonable contingencies that may occur. The requirements shall consider the entire range of Apollo project activities, and shall insure compatibility with the spacecraft design requirements and effective and reliable support of the spacecraft. The capabilities and limitations of man in the information flow channels shall be carefully evaluated to exploit his unique potentials without over-extending his physical limitations.

The basic mission requirements are the achievement of a maximum likelihood of mission success and crew safety. Consistent with these requirements, the information flow shall be held to a minimum, and kept simple in form, in order to allow simple and reliable support equipment and rapid ground system response.

3.1.3.1 Spacecraft-to-GOSS

The following in-flight spacecraft data shall be required in order to provide the real time or near real time spacecraft support functions listed in paragraph 3.1.1.

a. Crew

Earth orbit missions.- Physiological measurements shall be required in real time during early missions only, unless results of Mercury, Gemini, and the early Apollo missions suggest a need for data in later missions in order to provide early warning of conditions which might result in degraded crew performance or need to abort, and for which the crew monitoring may be only partially effective. Examples might be the monitoring of radiation dosage and predictions of expected mission dosage, or monitoring of a crew member to assure normal attentiveness. The crew data are required during earth orbit missions in order to study and verify spacecraft crew compatability and ability to perform under stressed conditions for extended periods in a realistic space environment.

Lunar Missions.- Physiological measurements shall not be required during lunar missions except when crew members are outside the spacecraft (on the lunar surface). In this case, measurements will be monitored by crew members inside the spacecraft, and significant data relayed to the ground by voice or telemeter. The lack of a requirement for crew data is not intended to preclude installation of crew monitoring consoles at the DSIF sites and MCC. A console having a capability of monitoring a single crew member, and having provisions for time sharing between members might be considered for installation at each station involved in lunar operations.

b. Systems Checkout and Status

Spacecraft Systems checkout and status parameters shall be monitored during all mission phases on a programmed or as required basis. Specific parameters shall be selected according to their importance in providing backup monitoring for malfunction analyses, and their ability to assist in maintaining real time or near real time estimates of mission or alternate mission capability.

Ascent Phase.- Booster and spacecraft systems data will be continuously monitored at the MCC and LCC, and will be used for orbit/abort decisions during boost.

Lunar Injection.-

Booster performance and spacecraft systems status data shall be monitored during injection to a translunar transfer trajectory from the parking orbit.

Other Flight Phases. - Spacecraft Checkout and systems status data will be monitored at appropriate ground stations. Cabin environment, radiation level, and cumulative radiation level shall be included.

c. Navigation and Guidance

GOSS generated navigation and guidance data are required in order to provide backup of the spacecraft navigation system and to verify spacecraft computer performance. GOSS computer inputs may be desired to verify guidance commands during periods when the earth based navigational sensors are more accurate than the spacecraft sensors. During the transearth phase of the lunar mission, data are required to allow verifying orientation of the inertial platform. During earth orbit missions guidance data are not required in real time, but must meet requirements for in-mission verification of maneuvers and other exercises, and of systems performance capability. During lunar missions, the data shall be processed and computations performed in near real time, in order to provide continuous backup capability, when required, for the spacecraft systems and decisions.

d. Tracking

Radar tracking data are required in real or near real time in order to maintain continuously updated trajectory data, and to assure that the spacecraft is on an acceptable trajectory for accomplishing the mission objectives. The ground based estimates of position and velocity will also be used to confirm performance of the spacecraft navigation and guidance system, and to alert and provide acquisition data to the down-range stations.

e. Abort Sensing

Development of operational plans to accommodate range safety and aborts requires extensive, exacting development and analysis of the automatic abort sensing system. Careful attention must be given to system reliability and comprehensive system logic. The system logic must incorporate and be compatible with range safety procedures, the launch vehicle data which must be supplied to the MCC, and the form in which the launch vehicle data are presented to the computer and displays.

3.1.3.2 Other Sources to GOSS

a. Spacecraft Systems and Trajectory Data

Spacecraft systems, booster performance and other trajectory data shall be required as stored inputs to the MCC Computer prior to the mission, in order to compute and evaluate mission flight profiles, and provide estimates of mission and alternate mission capability.

b. Earth and Solar Weather

Predictions of weather at landing stations are required in order to define mission schedules, recommend landing stations to the spacecraft, and coordinate recovery operations.

Predictions of high altitude weather shall be required for estimates of air density along the reentry trajectory.

Solar flare predictions shall be required for mission planning and during flight, to provide assurance against excessive radiation.

c. Electromagnetic Environment

Estimates of the electromagnetic environment shall be required for determining spacecraft-ground communications assignments and schedules.

d. Status of Remote Stations Communications Links and Recovery Forces

Remote station, point-to-point communications, and recovery forces status indication shall be required at the MCC in order to provide for coordination and control of the ground network.

3.1.3.3 GOSS to Spacecraft. - GOSS shall transmit the following data to the spacecraft by voice link:

a. Navigation and Guidance

GOSS measurements of position and velocity, and ground computed estimates of navigational inputs shall be available for transmittal upon request by the spacecraft, as a backup of the spacecraft determined guidance inputs. In addition, the MCC will advise the spacecraft commander whenever significant deviations occur between the programmed and actual spacecraft position and velocity.

b. General Support and Consulting

1. Mission capability. Results of analyses of mission capability (comparisons of actual vs. predicted values of remaining fuel, oxygen, and accumulated radiation change etc.) and alternate mission planning parameters, will be provided the spacecraft crew upon request, or as considered advisable by the controller.

2. Diagnosis. The GOSS will provide the spacecraft commander with information to assist in diagnosing causes of, and remedying malfunctions.

3. Earth and Solar Weather. The GOSS will provide the spacecraft commander with information on landing stations weather, and preferred stations for landing, based on weather conditions and deployment of recovery forces, and predictions

of solar flares. This information will be provided upon request of the spacecraft commander, or as deemed warranted by the GOSS controller.

c. Emergency

The GOSS will immediately inform the spacecraft commander of conditions which may require abort decisions or computations.

3.1.3.4 Display and Monitor Requirements

3.1.3.4.1 Display Parameters

3.1.3.4.1.1 Spacecraft Parameters. - Spacecraft parameters shall be selected for display based on the following criteria:

a. Contribution to overall mission effectiveness and crew safety.

b. Relative difficulty of crew monitoring and interpretation (Spacecraft displays apt to require detailed and prolonged attention or expert evaluation should be also displayed and monitored on the ground). Data such as meter readings displayed in the spacecraft, and for which history might be desired (a form of trend data), should be processed and stored on the ground so as to allow retrieval of the earlier data.

c. Value in determining mission capability and status, analyzing malfunctions, and backing up the navigation and guidance systems.

3.1.3.4.1.2 Ground Communications. - A display shall be provided at each station to indicate the status of all communications circuits that terminate at that station. For each circuit, the status displays shall indicate if the circuit is operative, degraded or out, or idle or binary.

3.1.3.4.2 Display Flexibility. - The MCC and remote station display systems should permit changing display parameters during and between missions.

3.1.3.5 Ground Data Processing and Computational Requirements. - In this specification, the term "data processing" will apply to functions involving the manipulation of incoming, outgoing, and internal data required to provide compatibility between data sources, data users, and computers. The term computation will apply to numerical or mathematical calculations (real or non-real time) required for determining the required trajectory and guidance data and for making the mission decisions.

3.1.3.5.1 Data Processing Requirements. -

Flexibility. The use of a combined automatic and manual data editing system should be considered in order to provide maximum display flexibility and to minimize the personnel and equipment required. The system shall allow for manually selecting parameters for local display

and monitoring. However, wherever possible, data shall be preselected for automatic editing and coding for teletype transmission to the MCC.

DSIF Display Consoles. The Woomera and Johannesburg DSIF stations shall have adequate displays to provide autonomous support of the spacecraft missions in the event of point-to-point communications difficulties.

3.1.3.5.2 Computational Requirements. - All computations for earth orbital flights and lunar missions shall be performed at the MCC computer facility with the following exceptions. The JPL computer may be used as a backup for lunar mission phases. The Woomera and Johannesburg DSIF stations shall be able to provide back up to the spacecraft navigation and guidance systems in the event of point-to-point communications difficulties.

3.1.3.6 Point-to-Point Communications. - The requirements for point-to-point communication will depend upon the configuration of the station and the role of the station in the Apollo Mission. During earth orbital missions the stations equipped with radar and data processors have requirements for transmitting trajectory and spacecraft data to MCC. The amount of spacecraft data that can be sent to the MCC, and therefore, the size of the data processor at the remote station, will depend upon the bandwidth of the communications links available. The same argument applies to the DSIF stations during the lunar missions. Requirement for wider bandwidth than teletype and voice is increased because of prolonged duration of the spacecraft over the single DSIF-type station. There are going to be slack periods in communications with the spacecraft which will be used to transmit the required information to the MCC. There are going to be, also, vital periods such as midcourse maneuver, landing, exploration and launch from the moon, when MCC would desire to receive and transmit large amounts of data from and to the spacecraft.

Not all the stations will have such a heavy responsibility assigned to them, although they have to meet minimum requirements as described below:

The remote station shall be connected to the MCC via a minimum of one full duplex teletype channel to satisfy basic operational and minimum administrative traffic requirements. In addition, each remote station shall be provided with continuous two-way voice with the MCC to support operation, administrative, and data backup communication requirements.

Whenever more than one circuit is provided between the MCC and a remote station, the circuits shall, if possible, be routed via alternate facilities to improve circuit reliability.

3.1.3.7 Summary of Information Flow Requirements. - The basic information flow is shown in Figure 2. Typical spacecraft-ground telemeter information required for monitor by GOSS, and ground-spacecraft information requirements are summarized in Table I, for 14-day manned earth orbit and lunar landing missions.

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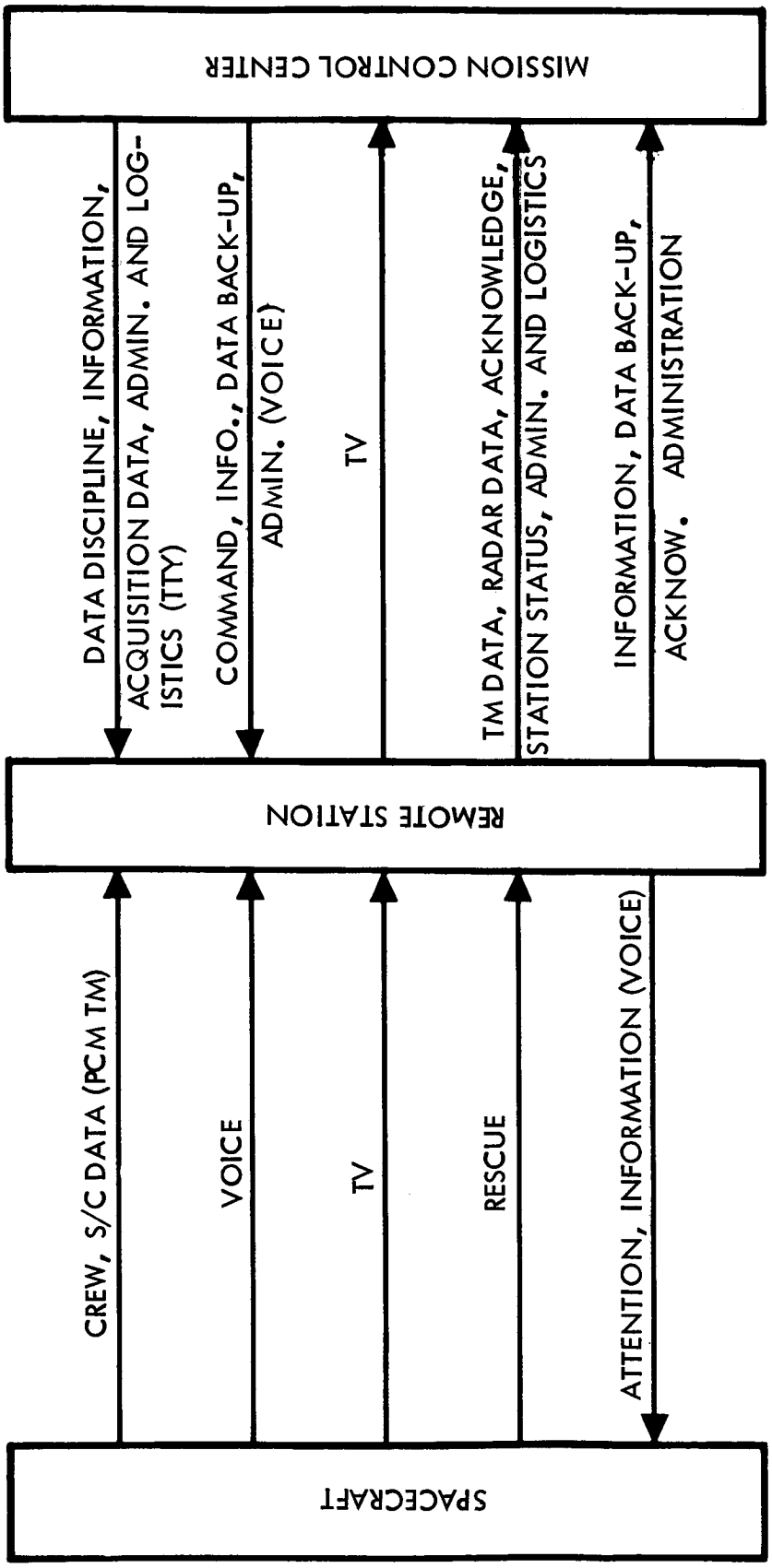

Figure 2. Information Flow Summary

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Table I. Typical Spacecraft Ground Telemetry Information Required for Monitoring by GOSS

Data Type	System	Item	Manned 14-Day Earth Orbit Mission	Lunar Landing Mission
Crew (1)	Crew	EKG	X	No
		Blood Pressure	X	
		Temperature	X	
		Respiration	X	Requirement (Self Monitoring and Voice Comm)
Environment	Cabin and Suit Environment	Vibration	X	X
		Acceleration	X	X
		Temperature	X	X
		Pressure	X	X
		Radiation	X	X
		Atmosphere Composition	X	X
		Leak Rate	X	X
Automatic Checkout	All systems	See *	X	X
Systems Status	Environmental Control			
	Liquid Cooling	C/M Reservoir level #1 and #2	Y	X
	Oxygen	Quantity	Y	X
	Re-entry Oxygen	Quantity		
	Nitrogen	Quantity	Y	X

*All measurements monitored as gross status checks during inflight automatic checkout.

X - Real time monitoring required.
Y - Delay acceptable.

Table I. (Cont)

Data Type	System	Item	Manned 14-Day Earth Orbit Mission	Lunar Landing Mission
Systems Status (Cont.)	Electrical Power			
	Fuel Cell	S/M H_2 level	Y	X
		S/M O_2 level	Y	X
	Instru-mentation	C/M Time	Y	X
	Communi-cations	C/M May Day	X	X
		C/M Mode Indication	X	X
	Service Propulsion	S/M fuel level	Y	X
		S/M oxidizer level	Y	X
		Propulsion on-off	Y	X
		Chamber pressure	Y	X
	Reaction Control Systems	C/M fuel level	X	X
		C/M oxidizer level	X	X
		C/M fuel leakage	Y	X
		C/M oxidizer leakage	Y	X
		C/M fuel remaining	Y	X
		S/M fuel remaining	Y	X
		S/M oxidizer remaining	Y	X
		On-off times	Y	X

X - Real time monitoring required.
Y - Delay acceptable.

Table I. (Cont)

Data Type	System	Item	Manned 14-Day Earth Orbit Mission	Lunar Landing Mission
Systems Status (Cont.)	Stabilization & Control	Attitude (pitch, roll, yaw)	X	X
	Mechanical Earth Landing Impact Attenuation	Event times Time	X	X
	Launch Escape Systems	C/M Separation Time	X	X
	Lunar Landing Module		Y	X
	Boosters	Lift-off time Ignition and cut-off times Booster separation times (All other booster data to LCC only)	X	X
Navigation & Guidance	Inertial System			
	Platform servo loops	C/M gimbal angle readout	Y	X

X - real time monitoring required.
Y - delay acceptable.

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Table I. (Cont)

Data Type	System	Item	Manned 14-Day Earth Orbit Mission	Lunar Landing Mission
Navigation & Guidance (Cont.)	Optics	C/M precession angle	Y	X
		C/M prism angles	Y	X
		C/M Shaft angles	Y	X
		Telescope angles	Y	X
	Display Inputs	Trajectory error	Y	X
		Trajectory correction	Y	X
		Position (x, y, z) or	Y	X
		Orbit data	Y	X
		Velocity	Y	X
		Acceleration	Y	X
		Attitude	Y	X
		Retro time	X	X
Tracking	Ground Radars S/C Transponders	Trajectory data	X	X

X - real time monitoring required.
Y - delay acceptable.

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3.2 Tracking Communications and Landing Site Requirements

The tracking communication and landing site requirements have been established as necessary for the GOSS to carry out the GOSS functions stated in paragraph 3.1.1, consistent and compatible with the overall Apollo operational concept as specified in the Statement of Work, the Apollo Mission Performance Specification, and the Spacecraft Performance Specification.

3.2.1 Coverage Requirements

3.2.1.1 Radar Tracking

3.2.1.1.1 Earth Orbital Missions

3.2.1.1.1.1 Ascent. - There shall be continuous tracking throughout the ascent phase of the missions including the injection into orbit.

3.2.1.1.1.2 Earth Orbit. - There shall be sufficient radar coverage immediately following injection into orbit to permit evaluation of the ability of the spacecraft to continue its mission for at least one orbit. The coverage during the first orbit must be sufficient to define the orbital parameters so as to enable prediction of mission capabilities up to 14 days in length. Radar coverage for subsequent orbits must be adequate for evaluating orbital maneuvers, rendezvous, navigation exercises, and initial conditions of de-orbiting for recovery.

3.2.1.1.1.3 Orbit Ejection and De-orbit Coast Phases. - Coverage of the orbit ejection for landing at the primary landing site shall involve acquiring the spacecraft during the following de-orbit coast phase. The orbit ejection coverage combined with de-orbit coast coverage shall be adequate for predicting with high accuracy the position, velocity, and angle of entry into the atmosphere.

For landings at the secondary and alternate landing sites the coverage of the orbit ejection and/or de-orbit coast phases should, if possible and practical, provide a reasonable prediction of the atmosphere reentry trajectory.

3.2.1.1.1.4 Entry. - The atmosphere entry phase for landings at the primary landing site shall be completely covered by radar, if possible and practical, to give a highly accurate impact prediction and a high assurance of acquisition of the spacecraft in the recovery phase. This coverage must allow for reasonable degrees of "over-shoot" and "under-shoot."

The entry phase for landings at the secondary and alternate landing sites should, if possible, have coverage to improve landing prediction.

3.2.1.1.1.5 Recovery. - One hundred percent coverage of the recovery phase shall be provided by the radar equipment of the recovery forces at the primary, secondary, and alternate landing sites. Adequate allowance shall be provided for "over-shoot" and "under-shoot" situations.

3.2.1.1.2 Lunar Missions. - The radar tracking coverage requirements specified here apply to all types of lunar missions.

3.2.1.1.2.1 Ascent to Parking Orbit. - Same as in para. 3.2.1.1.1.1.

3.2.1.1.2.2 Parking Orbit. - There shall be sufficient radar coverage of the parking orbit, resulting from launches on any heading within the launch window, for the determination of accurate orbital data for verification of spacecraft-determined initial conditions of injection into the trans-lunar phase. This determination of accurate orbital data must be achievable in time to support the injection phase, allowing time before injection for the computation of and preparation for the injection phase program. How soon after launch the injection phase will occur must be established to fix this constraint on the tracking coverage of the GOSS. This depends on two major factors (other than the required injection for a particular mission), checkout of the spacecraft and the S-IV booster stage.

The radar must provide for coverage of the spacecraft in case of an abort of the lunar mission prior to injection into the translunar phase. In such a case, an alternate earth orbital mission capability may be defined by the MCC. An immediate recovery or a mission of several days may be defined. The radar coverage requirements for these are the same as those defining the Earth Orbit, Orbit Ejection, De-orbit Coast, Entry, and Recovery phases of the Earth Orbital Mission, para. 3.2.1.1.1.

Radar coverage shall be provided to support earth orbital rendezvous maneuvers as may be required prior to injection into the translunar phase.

3.2.1.1.2.3 Translunar Injection. - The powered injection into the Translunar Phase shall be covered by radar completely to provide highly accurate acquisition data for the subsequent coverage of the translunar phase.

3.2.1.1.2.4 Translunar Phase. - The initial part of the Translunar Phase shall be covered adequately to provide accurate determination of the trajectory parameters with 15 minutes of the termination of powered flight. Coverage of the spacecraft by remote stations for near-earth tracking is highly desirable up until the time when a DSIF station can assume the tracking.

There shall be the capability for continuous tracking coverage except when not feasible when the spacecraft is on the far side of the moon.

3.2.1.1.2.5 Mission Phases in the Vicinity of the Moon. - There shall be the capability for continuous tracking coverage of the spacecraft except when not feasible (e.g., when the spacecraft is on the far side of the moon).

3.2.1.1.2.6 Transearth Phase. - There shall be the capability for continuous tracking coverage throughout this phase except on the far side of the moon and in the approach to the earth. The coverage of the spacecraft approaching the earth must be adequate to evaluate with high accuracy the position, velocity, and entry angle into the atmosphere after final course corrections are applied.

3.2.1.1.2.7 Entry. - The atmosphere entry phase for landings at the primary and secondary landing sites shall be completely covered by radar, if possible and practical, to give a highly accurate impact prediction and a high assurance of acquisition of the spacecraft in the recovery phase. This coverage must allow for reasonable degrees of "over-shoot" and "under-shoot."

3.2.1.1.2.8 Recovery. - One hundred percent coverage of the recovery phase shall be provided by the radar equipment at the primary and secondary landing sites with adequate allowance for "over-shoot" and "under-shoot."

3.2.1.2 Communications. - The communications coverage requirements given here are applicable to both telemetry and voice contacts.

3.2.1.2.1 Earth Orbital Missions. - The GOSS shall be capable of communication with the spacecraft at all times in the mission phases that the spacecraft is covered by radar. In addition, the GOSS must provide a communications contact with the spacecraft at least once every orbit.

3.2.1.2.2 Lunar Missions. - The GOSS shall be capable of communications with the spacecraft at all times in the lunar mission phases that the spacecraft is covered by radar. The GOSS must be capable of initiating communication at all times during the lunar missions that the spacecraft is in line-of-sight of an appropriate GOSS station.

3.2.1.3 Landing Site Requirements. - The primary and secondary landing sites are specified in the Apollo Mission Specification as follows:

Primary: 29.48° N lat. and 99.00° W long. (near San Antonio, Texas.)

Secondary: 29.48° S lat. and 135.00° E long. (near Woomera, Australia.)

3.2.1.3.1 Alternate Landing Sites. - Alternate landing sites shall be provided in order that the spacecraft can abort out of any earth orbit into an alternate landing site or the primary or secondary landing sites, based on

the spacecraft performance (particularly, the lateral range capability) specified in the Spacecraft Performance Specification.

3.2.1.3.2 Launch Pad and Ascent Abort Recovery Requirements. - Recovery facilities will be provided to recover the spacecraft in the cases of an abort off the launch pad or at any time during the ascent phase of either Earth Orbital or Lunar Missions.

3.2.2 GOSS Station Selection Criteria. - The criteria presented in this paragraph are in addition to the assumptions in paragraph 3.0 and the coverage requirements in paragraph 3.2.1.

3.2.2.1 Assumptions. - These assumptions are made, based on simple logic, engineering experience, and common sense.

a. The number of new stations should be kept to a minimum.

b. Stations selected to provide radar coverage will be assumed to have communications capability (telemetry and voice).

c. Use of stations in politically unstable and unfriendly countries shall be avoided.

d. The stations should be selected so as to minimize the logistic support problems involved.

e. Ground communications links should be kept as short and direct as possible.

f. The GOSS configuration should be kept as flexible as possible to permit modifications as the program plans change during development and to provide the operational flexibility necessary for the various Apollo missions.

3.2.2.2. Station Selection Criteria For Earth Orbital Mission. - A circular orbit inclined at 31.88° and at an altitude of 139 n. m. is assumed for purposes of evaluation and selection of stations. This altitude was chosen because it is the minimum orbit altitude for a 14 day earth orbital mission. The launch azimuth from Cape Canaveral was taken as 75° resulting in a ground track very similar to the Mercury capsule.

3.2.2.2.1 Radar Range Criterion For Station Selection. - The radar range of remote stations is assumed (conservatively) to be line-of-sight with a 5° horizon mask.

3.2.2.2.2 Communications Range Criterion For Station Selection. - The communication range is assumed to be line-of-sight to the real horizon.

3.2.2.2.3 Landing Sites Selection Criteria. - The spacecraft performance factor having major bearing on the landing site selections is the lateral maneuver capability, taken to be sufficient to permit the spacecraft to land out of 3 successive orbits at any site located at 29.48° N or S latitude (Spacecraft Performance Specification).

The general radar coverage requirement already stated was considered to be a major factor in the selection of the alternate landing sites. Selection of sites should consider the use of any radar coverage of the orbit ejection, de-orbit coast, or entry phases that could be provided by stations previously selected to satisfy orbital coverage. The size, shape, and position of the orbit ejection, de-orbit coast, entry, and recovery phase relative to a landing site shall be taken from the Spacecraft Performance Specification as well as necessary spacecraft performance data during these phases.

Advantage should be taken of available communications coverage of the orbit ejection, de-orbit coast, or entry phases since this coverage is also valuable in aiding the prediction of the landing impact point as an aid to the prompt and successful recovery of the spacecraft. No preference for day or night recovery operations is assumed.

3.2.2.3 Station Selection Criteria For Lunar Missions. - The lack of specificity in the near-earth phases at the start of all lunar missions prevents the presentation of firm criteria for the GOSS configurations to serve these missions. This lack of definition, however, emphasizes the need for a flexible GOSS to satisfy possible program changes as well as to support, in Apollo and even later space efforts, varied approaches to space navigation and utilization. To facilitate study of the problem of lunar mission coverage, the following assumptions were made:

a. The communications coverage requirements for Lunar Missions are the same as the radar coverage requirements (paragraph 3.2.1.2.2). Thus, the radar coverage analysis will be applicable to the communications.

b. Since the primary and secondary landing sites have been selected, no criteria are presented herein. (See Apollo Mission Specification)

c. A launch window of 4 hours corresponding approximately to launch azimuths from Cape Canaveral between 75 degrees and 105 degrees is assumed. These numbers are subject to change as the full significance of launch window trade-offs with GOSS coverage is developed and the launch operations needs for the launch window are established.

d. A circular parking orbit at 100 nm altitude is assumed for either a direct injection into the translunar phase or an earth orbital rendezvous approach to achieving the mission. While the rendezvous technique might use a higher altitude, the coverage, if adequate for the 100 n. m. orbit, would be adequate for the higher altitude.

e. Planning for lunar missions must be able to accommodate mission planning aspects such as days when a landing can be made at San Antonio or Woomera, the length of a lunar mission from 6 to 14 days, the time of the lunar day or night that is desirable for the stay on the lunar surface, and the desirability of recovery on earth in daylight. This requires that the GOSS must be prepared to cover the near-earth phases of the resulting missions without imposing further, undue constraint on the mission planning.

f. Trajectory data for the critical near-earth phases of the lunar missions (ascent, injection into translunar, entry and recovery) are taken from the Spacecraft Performance Specification.

3.2.2.3.1 Radar Range Criteria for Station Selection. - The radar range of stations for coverage of near-earth phases of the lunar missions is assumed to be line-of-sight with a 5-degree horizon mask, but limited to 32,000 nautical miles. (The applicability of this range depends upon the use of compatible equipment in the spacecraft which is not now specified for the spacecraft. Thus, in analysis of the coverage problem as part of the station selection process, this range limitation will be considered a variable whose influence on the problem shall be evaluated.)

The radar range of the DSIF stations for coverage of the translunar, transearth, and near-lunar phases shall be taken to be as represented in Figure 3.

3.2.3 General GOSS Configuration. - The stations selected to satisfy the requirements of paragraph 3.2.1 and according to the criteria of paragraph 3.2.2 are presented in this paragraph. Figure 4 presents the basic GOSS configuration selected to serve Earth Orbital Missions and, supplemented by remote station ships, to serve Lunar Missions.

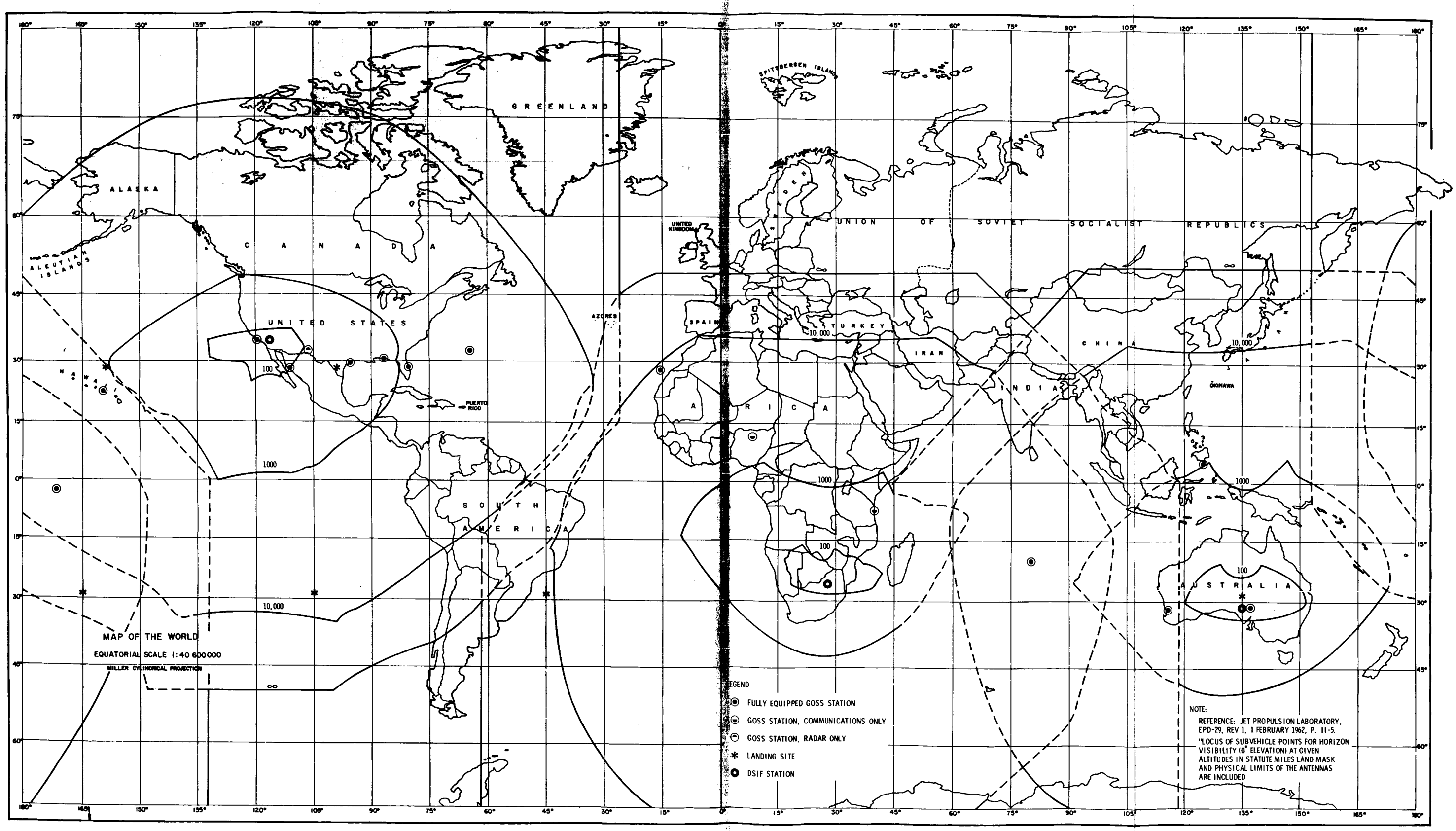

Figure 3. DSIF Station Coverage Capability

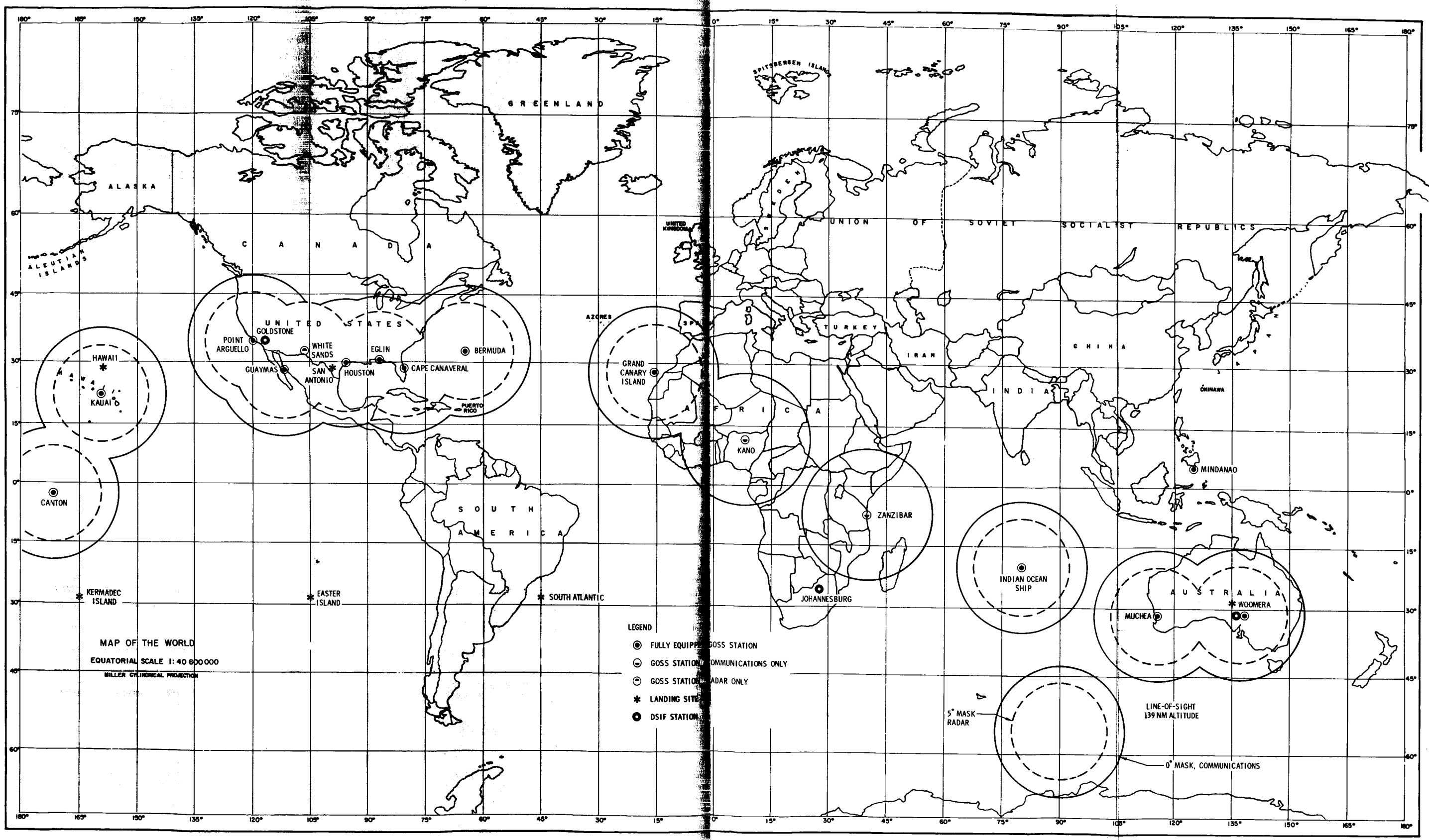

Figure 4. GOSS Station Location

3.2.3.1 Stations Selected for Earth Orbital Missions.

3.2.3.1.1 Evaluation of Current Mercury Network. - The current Mercury Network was first evaluated with respect to the radar and communications coverage requirements. It was established to be adequate. See Appendix A. Redundancy of coverage across the Southern United States occurs but changes are not recommended. It is felt that there is no need for a ship station between Bermuda and the Grand Canary Islands.

3.2.3.1.2 Selection of Houston. - It is recommended that a fully-equipped remote station (radar, T/M, and voice) be established at Houston. This obviates any need for one at Corpus Christi. This recommendation is based on the desirability of integrating the Apollo mission planning; the GOSS simulation, procedural, and mission rules development; and the GOSS personnel and astronaut training at the site of MSC and the MCC. To summarize, the stations 1 through 15 of Table II satisfy the radar and communications coverage requirements of the orbital phase of the earth orbital mission.

Table II. GOSS Stations & General Requirements

No.	Station Name	Type	Lat.	Long.	Radar	T/M	Voice
1	Cape Canaveral	Basic Mercury Network	28.5N	80.6W	X	X	X
2	Bermuda		32.4N	64.7W	X	X	X
3	Grand Canary Is.		27.7N	15.6W	X	X	X
4	Kano		11.6N	8.3E		X	X
5	Zanzibar		7.3S	39.3E		X	X
6	Indian Ocean Ship		20.0S	80.0E	X	X	X
7	Muchea		31.6S	115.9E	X	X	X
8	Woomera		31.2S	137.1E	X	X	X
9	Canton		2.8S	171.7W	X	X	X
10	Kauai		22.2N	159.6W	X	X	X
11	Point Arguello		34.6N	120.6W	X	X	X
12	Guaymas		28.0N	110.8W	X	X	X
13	White Sands		32.4N	106.4W	X		X
14	Houston		29.4N	95.2W	X	X	X
15	Eglin		30.5N	86.8W	X	X	X
16	Mindanao	New	5.0N	125.0E	X	X	X
17	San Antonio	Landing Sites	29.48N	99.00W	X		X
18	Woomera		29.48S	135.00E	X		X
19	Hawaiian Ship		29.48N	159.00W	X		X
20	Kermadec Is.		29.48S	165.00W	X		X
21	Easter Is.		29.48S	105.00W	X		X
22	S. Atlantic Site		29.48S	45.00W	X		X
23	Goldstone	DSIF	35.39N	116.85W	X	X	X
24	Johannesburg		25.89S	27.68E	X	X	X
25	Woomera		31.38S	136.89E	X	X	X

3.2.3.1.3 Alternate Landing Sites. - Stations 19 through 22 in Table II are the selected alternate landing sites. See Appendix A for supporting information. The exactness of locations, as may be inferred from the latitude and longitude coordinates, is not intended. However, the effectiveness of coverage of any landing site is reduced by changing its latitude since its latitude is optimized for the spacecraft's lateral range capability during the de-orbit phase. If the spacecraft's lateral range in the total orbit-to-landing phases were to be increased over that specified in the spacecraft specification, the set of landing sites could be moved to a lower latitude (toward the equator) and possibly reduced in number. The longitudes are much less critical; they could be changed several degrees without reducing coverage. Further analysis is expected to indicate some movement to maximize the coverage.

A landing site not shown in Table II, but which will exist and will be a redundancy for the Woomera site, will be located in the North Atlantic Ocean. Some of the recovery forces in that area that are needed to handle any aborts off the launch pad or during the ascent phase should be regrouped after the launching about a position centered at 29.48 degrees latitude and 39.00 degrees W longitude.

3.2.3.1.4 Supplemental Radar Coverage for Landing Sites. - Analysis performed to date shows that the selected landing sites require some supplemental radar coverage to ensure their effectiveness. See Figure 5.

The Hawaiian site, which is operationally ideal, requires radar coverage during the orbit ejection phase and/or its de-orbit coast phase to ensure reasonable impact prediction and prompt recovery. A station located near the southern tip of Mindanao would satisfy this need and provide some radar coverage of the orbit ejection phase for landing at Kermadec Islands site, as well.

The Easter Island site would be provided with good de-orbit coast phase coverage by radar at the Canton Station and at the Kermadec Island landing site. (Additional requirement for radar at Canton Island is indicated in the analysis of coverage of the injection phase and the entry phase of lunar missions.)

The coverage of landings at Woomera is improved by movement of the Indian Ocean Ship from its current location to 20.00 degrees S latitude and 80.00 degrees E longitude.

The South Atlantic landing site has little or no coverage from existing stations. A ship station near 12.00 degrees S latitude and 110.00 degrees W longitude is indicated, but further study of the total problem is needed to support a firm requirement.

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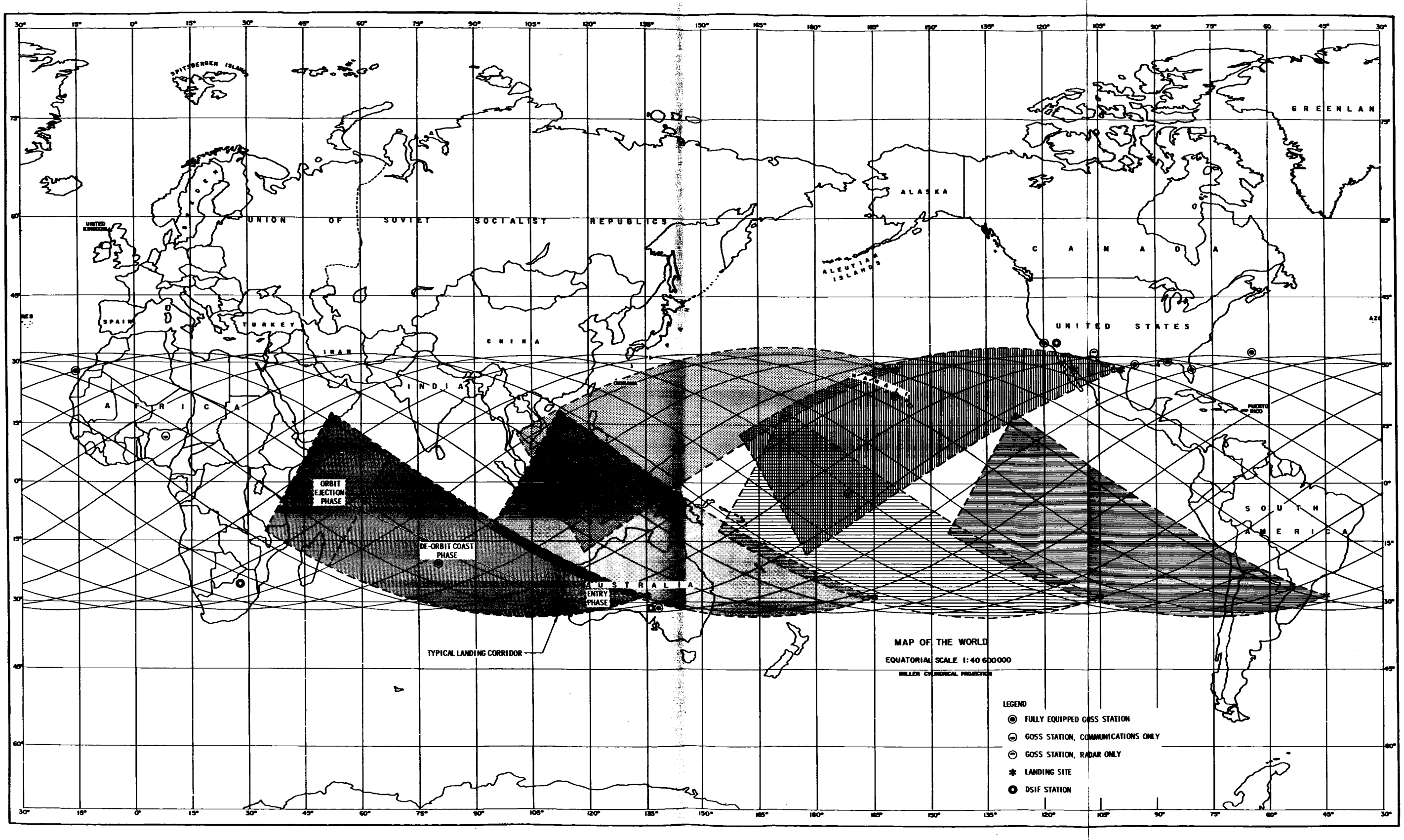

Figure 5. Entry Corridors for Landing Sites

3.2.3.1.5 Orbital Coverage Re-evaluation. - With the addition of the Mindanao station alone, preliminary analysis indicates that the coverage of the orbital phase of earth orbital missions is improved such that the longest time interval between communications contacts will be nearer an hour than an orbital period.

Voice communication (or voice and telemetry) capability at the Kermadec Islands, Easter Island and So. Atlantic landing sites would further decrease the out-of-contact time. The value of voice only communication capability at these stations would be great in emergency abort situations requiring instantaneous de-orbit from north-bound orbit to landings anywhere in the Southeast Pacific region. Further analysis of this problem area is indicated.

3.2.3.2 Stations Selected for Lunar Missions. - Analysis of the station requirements for radar and communications coverage of the lunar missions is not complete. Preliminary results indicate that a highly flexible coverage scheme is desirable to accommodate the planning restrictions of other mission planning factors. This flexibility can be achieved by the use of fully-equipped ships (radar, T/M, and voice) to complement the coverage of the near-earth phases, the ascent through the early translunar and the late transearth through the entry mission phases.

3.2.3.2.1 Stations for Ascent Coverage. - The radar and communications coverage of the ascent trajectories of all possible launch azimuths from Cape Canaveral between 75 degrees and 105 degrees (four-hour launch window) are assumed to be covered by facilities of AMR and Bermuda.

3.2.3.2.2 Radar Stations for Parking Orbit Coverage. - Bermuda and AMR will cover the initial portion of the parking orbit phase and provide adequate orbit definition to establish the safety of the spacecraft to proceed in orbit.

The first up-grading of orbital data for all azimuth launches will be provided by the Grand Canary Island station and the facilities of AMR. (The latter could be replaced by a ship station if AMR cannot provide this coverage.)

The next trajectory up-grading will be provided to all orbits (within launch azimuth limitations) by the Indian Ocean Ship, moved for this mission to a position of approximately 25.00 degrees S latitude and 75.00 degrees E longitude. (This movement would reduce effectiveness of de-orbit coast coverage for a landing at Woomera in the event the lunar mission were aborted prior to injection in translunar.) This up-grading of orbit data would be achieved just prior to the area of possible injection points associated with the "long coast" injection area. (See Spacecraft Performance Specification.)

The data on orbital parameters provided by this coverage should be adequate for the injection. Any planning to use the latter part of the "short coast" injection on the first orbit would depend on establishing the adequacy of the radar coverage prior to contact of the Indian Ocean Ship or providing more coverage.

Coverage of the parking orbit after an abort prior to injection phase is the same basic problem faced by the earth orbital mission, requiring that the GOSS for the earth orbital mission remain basically intact for the lunar missions.

3.2.3.2.3 Communications Stations for Parking Orbit Coverage. - The unique communications coverage requirements for the parking orbit stem from the requirement to support the spacecraft in its systems checkout and the checkout of the S-IV booster in preparation for the injection phase. The radar stations covering the parking orbit, Kano and Zanzibar, would support this activity. However, the adequacy of this coverage has yet to be evaluated, since the explicit role of GOSS in this activity and the requirements of this activity are yet to be established as a basis for further communications coverage requirements definition.

3.2.3.2.4 Radar and Communication Stations for the Injection Phase and the Early Translunar Phase. - The use of fully-equipped ships to supplement the already selected remote sites to satisfy the coverage requirements in these phases is being studied. The adequacy of the current three DSIF stations in taking over the coverage from the near-earth stations is part of this study. Use of the northern part of the "long coast" injection appears to be desirable for the following reasons:

a. Ship stations used can be subsequently used in the coverage of the entry phase.

b. The early translunar phase will pass over the United States stations. See Figure 6.

Results will be presented in the next specification revision.

3.2.3.2.5 Radar and Communication Stations for the Late Transearth and Entry Phases. - The selection of ship station positions and an evaluation of the current three DSIF stations to cover these phases is closely associated with the problem covered in the paragraph immediately above. Selections will be presented in the next revision of this specification.

3.2.3.2.6 Landing Station Selections. - San Antonio and Woomera are specified in the Spacecraft Performance Specifications as the landing sites for lunar missions. The specification of the configuration of the recovery

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ase Coverage for Lunar Missions

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force to handle aborts off the launch pad and during ascent is not appropriate as a subject for this specification. The integration of it into the GOSS network does represent a requirement for GOSS.

3.3 Point-To-Point Ground Communications Mode Requirements.- The point-to-point ground communications shall be accomplished by a combination of teletype, voice circuits, and high speed data links, which shall be reliable in operation and capable of quick conversion from a general use status to a mission status for tracking and communication with the Apollo spacecraft. Many of the circuits and terminal equipments along with the necessary operations and maintenance services are leased. The inter-station communications links between the MCC and each of the remote stations are shown on the maps given in Figure 7 and 8 for the 1962 and 1964 time periods, respectively. The communications routings are shown on the charts, Figures 9 and 10.

Station 1 - Cape Canaveral.- Facilities are available to satisfy requirements for voice, teletype, high speed data, and television. The facilities in the AMR as far downrange as Puerto Rico are connected via cable to Cape Canaveral. This cable is in the process of being extended to Antigua.

Station 2 - Bermuda.- All communication requirements except TV will be satisfied by utilizing the submarine cable to New York, and commercial network facilities from New York to the MCC.

Station 3 - Grand Canary Island.- Present circuits consist of one voice and two teletype channels via HF radio to London, then via cable to New York, and then via commercial network facilities to the MCC.

Station 4 - Kano, Nigeria.- The present circuit consists of voice and two teletype channels to London via HF radio, then via cable to New York. A more reliable circuit with voice capability will be available in 1964 with the installation of the British Commonwealth cable from Bathurst (on the western coast of Africa) to London. Kano will be connected to Bathurst via HF radio.

Station 5 - Zanzibar, Tanganyika.- The present circuit consists of voice and two teletype channels via HF radio through Kano, Nigeria, to London.

Station 6 - Indian Ocean Ship.- The present circuit consists of voice and teletype via HF radio to Perth and then by land line to Sydney. See Station 7 discussion for the Sydney to MCC routing.

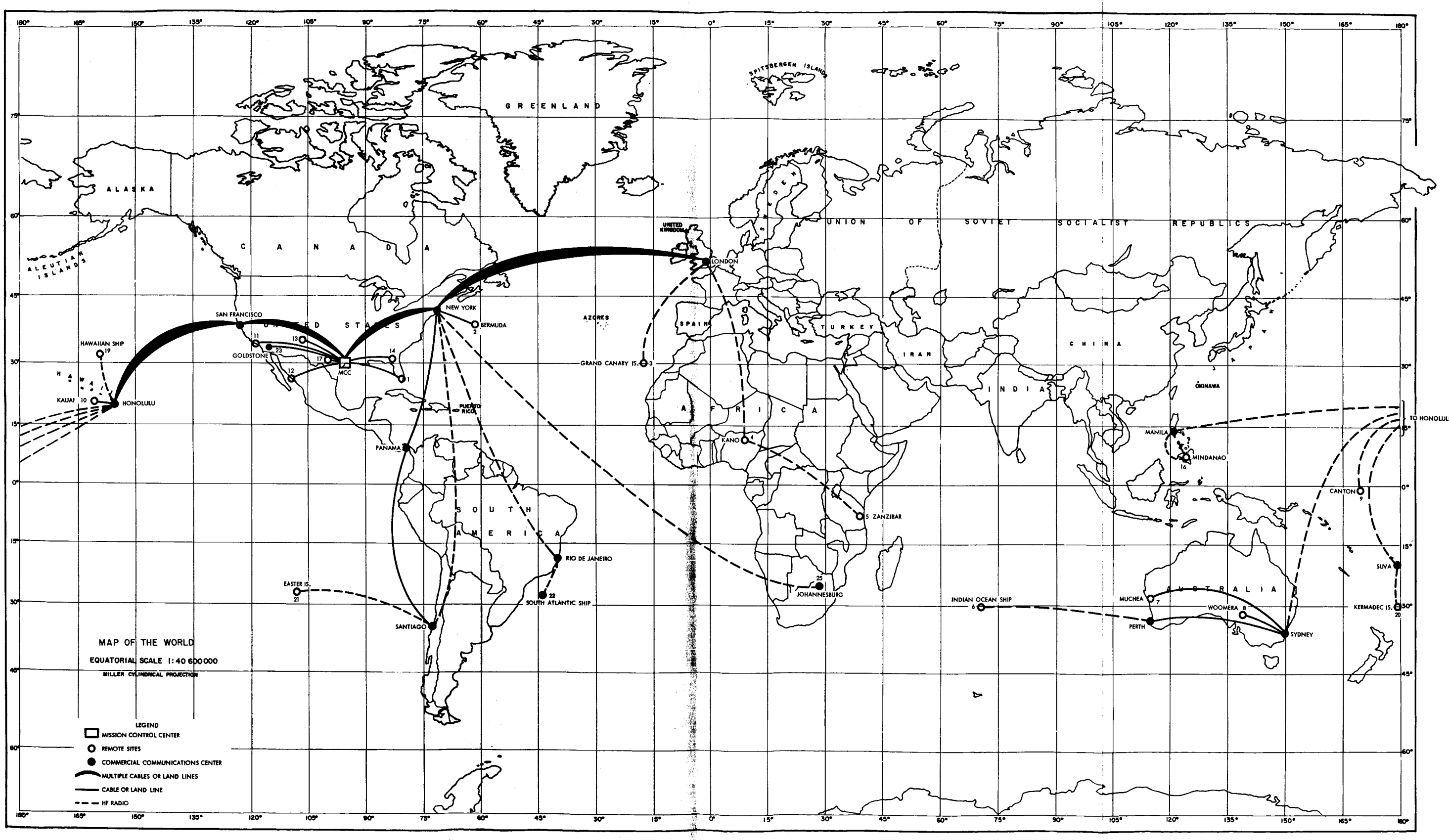


Figure 7. Primary Communication Routing Map 1962 Availability

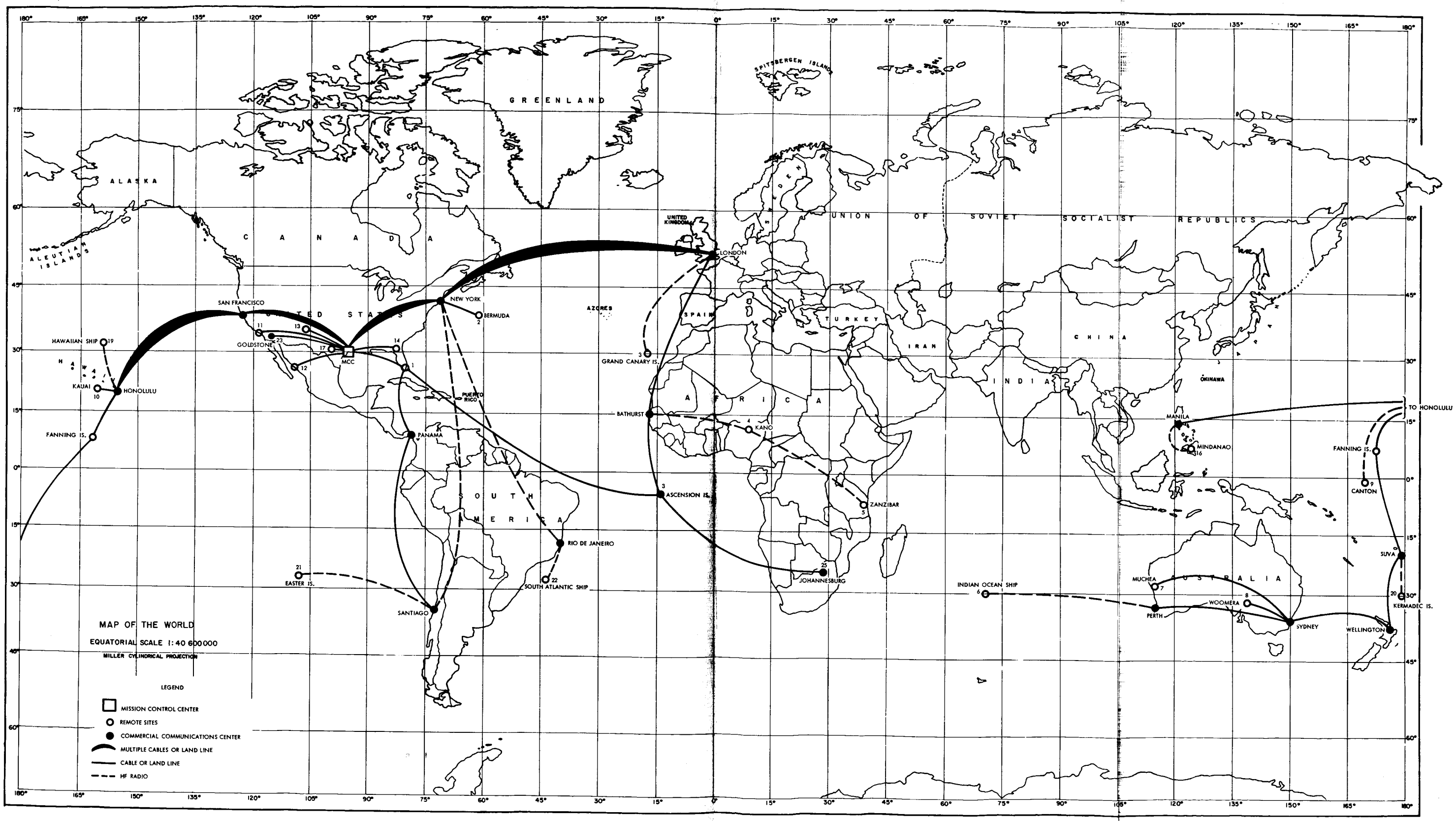
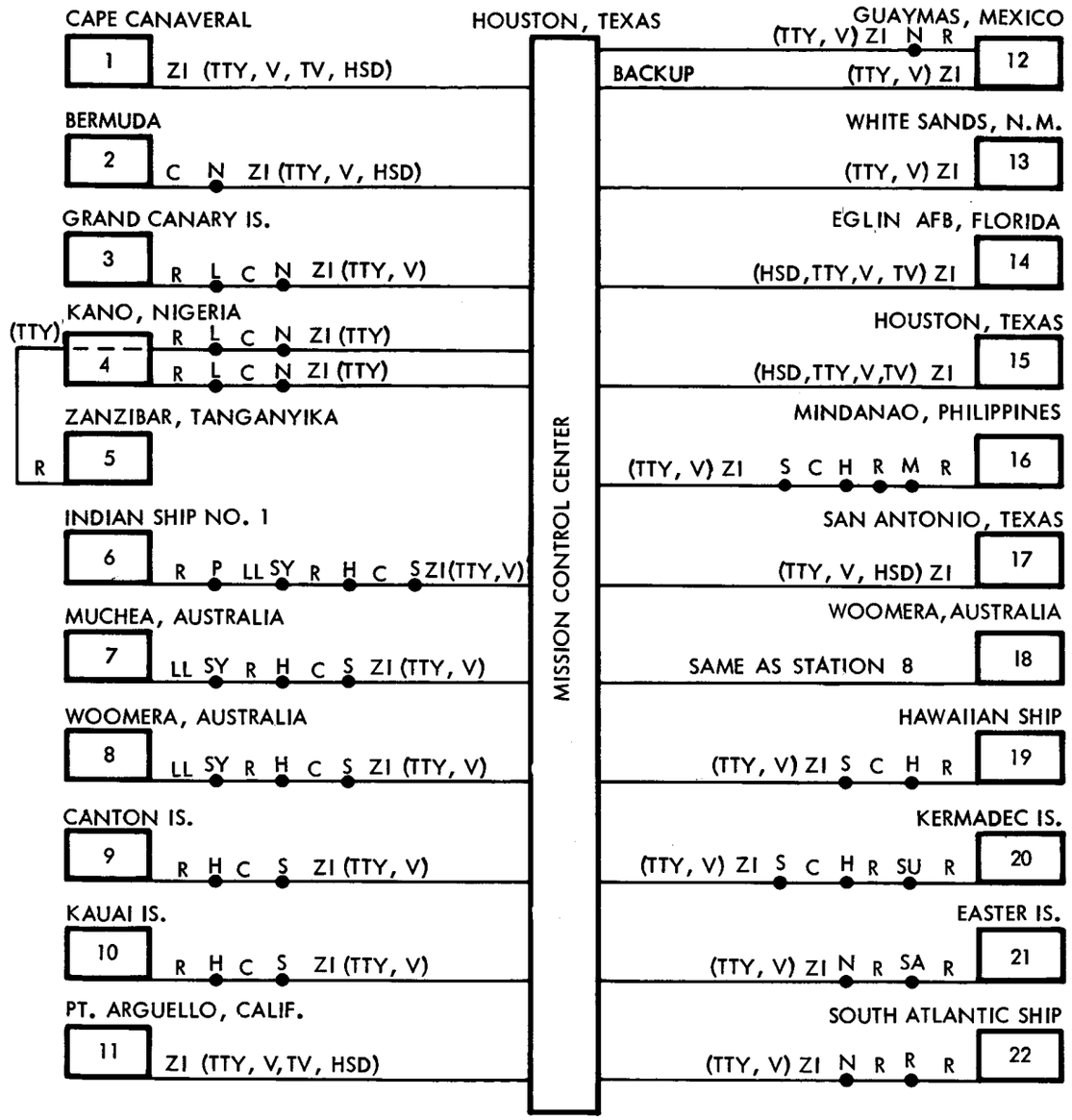


Figure 8. Primary Communication Routing Map 1964 Availability



LEGEND

N	VIA NEW YORK	R	HF RADIO	TV	TELEVISION (ANALOG)
L	VIA LONDON	C	SUBMARINE CABLE	HSD	HIGH SPEED DATA
S	VIA SAN FRANCISCO	LL	LAND LINE	M	VIA MANILA
SY	VIA SYDNEY	ZI	USA COMMERCIAL	SA	VIA SANTIAGO
H	VIA HONOLULU	V	VOICE	SU	VIA SUVA, FIJI IS.
P	VIA PERTH	TTY	TELETYPE	R	VIA RIO DE JANEIRO

Figure 9. Communications Facilities Diagram 1962 Availability

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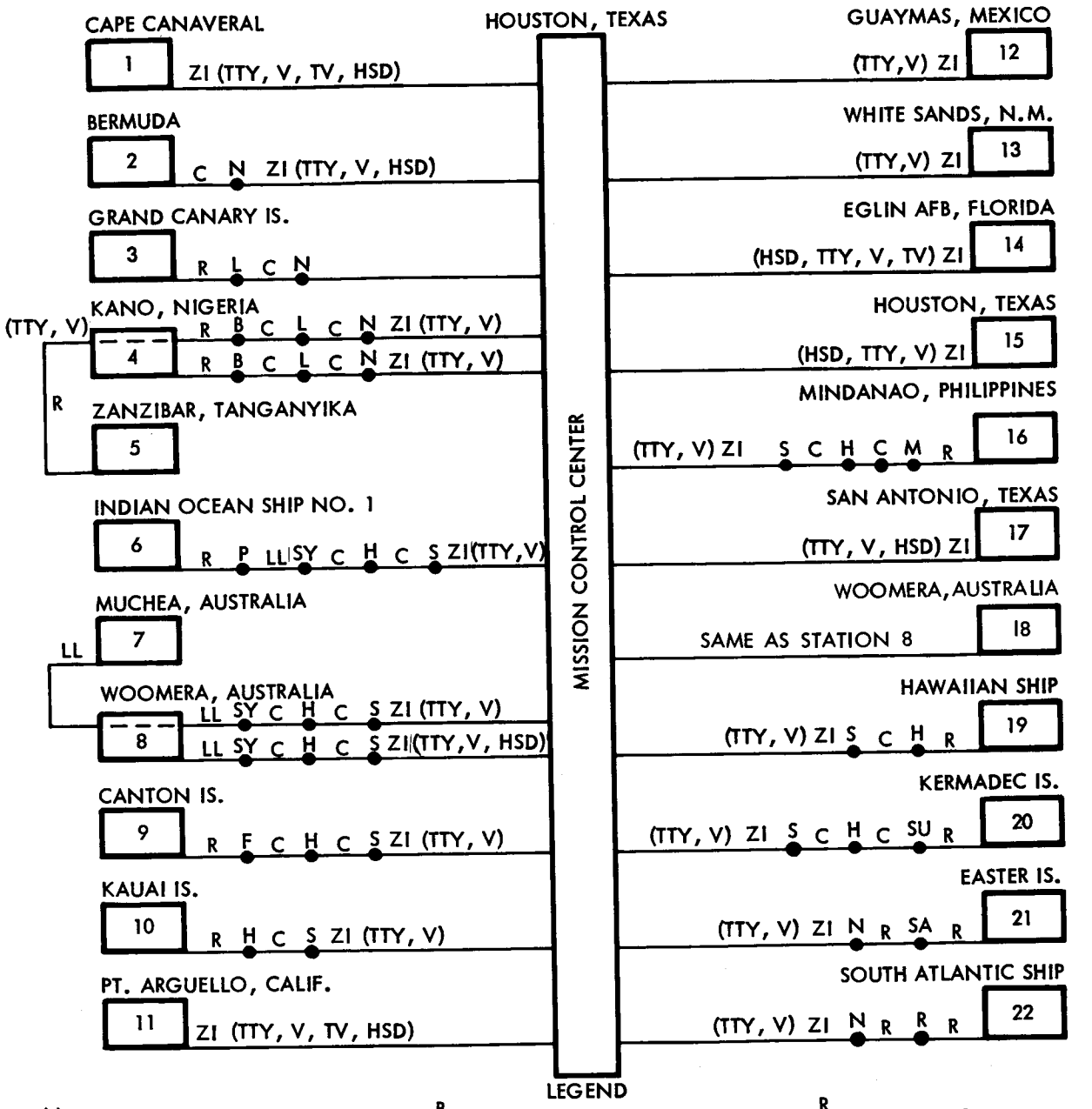

Figure 10. Communications Facilities Diagram 1964 Availability

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Station 7 - Muchea, Australia. - The present circuit consists of voice and teletype channels via land line to Sydney, via HF radio to Honolulu, and then via cable to San Francisco. A more reliable submarine cable installation is planned by PMR linking Honolulu with Australia via New Zealand and the Fiji Islands.

Station 8 - Woomera, Australia. - The comments for Station 7 are applicable to this station, except that a high speed data link is contemplated.

Station 9 - Canton Island. - With the installation of the trans-Pacific cable from Honolulu to Sydney by 1964, this station will provide improved reliability for voice and teletype via HF radio to Fanning Island (a submarine cable relay site). The remainder of the route would be over cable and commercial facilities to the MCC.

Station 10 - Kauai Island. - Present circuits include one or more teletype channels, possible data, and a voice channel via microwave to Honolulu via cable to San Francisco, and then via commercial network facilities to the MCC.

Station 11 - Point Arguello, California. - Facilities are available and may be provided to satisfy requirements for voice, teletype, high speed data, and television, if required.

Station 12 - Guaymas, Mexico. - Voice and teletype will be available with a high degree of reliability because these circuits may be routed over land lines to the U. S. commercial network, or, via the HF radio to New York. This option will provide alternate routing, if required.

Station 13 - White Sands, New Mexico. - Same as Station 11.

Station 14 - Eglin Air Force Base, Florida. - Same as Station 11.

Station 15 - Houston, Texas. - Same as Station 11.

Station 16 - Mindanao, Philippines. - Voice and teletype service could presently be provided via HF radio to Manila and then to Honolulu, then by cable to San Francisco. Installation of the Manila-Guam-Honolulu submarine cable in 1965 will increase the reliability of this circuit.

Station 17 - San Antonio, Texas. - Same as Station 11.

Station 18 - Woomera Landing Station. - See Station 8.

Station 19 - Hawaiian Ship. - Voice and teletype service could be provided via HF radio to New York thru Rio De Janeiro, then via commercial facilities to the MCC.

Station 20 - Kermadec Islands. - Voice and teletype service could presently be provided via HF radio through Sydney to Honolulu and then via cable to San Francisco. Installation of the Honolulu-Fiji Island-New Zealand-Australia submarine cable in 1964 would increase the realibility of this circuit. The circuit then would be routed via HF radio to Suva, Fiji Islands, and via cable through Honolulu to San Francisco.

Station 21 - Easter Island. - Same as Station 18.

Station 22 - South Atlantic Ship. - Voice and teletype service could be provided via HF radio to New York thru Rio De Janeiro, then via commercial facilities to the MCC.

DSIF-Point-To-Point Ground Communications. -

Station 23 - Goldstone, California. - Facilities are available and circuits may be provided via commercial network facilities to MCC for voice, teletype, high speed data, and television.

Station 24 - Woomera, Australia. - See Station 8 under Remote Station Point-To-Point Ground Communications.

Station 25 - Johannesburg, South Africa. - Present circuits consist of a voice link to London via HF radio and then via cable to New York, and a teletype channel directly to New York via HF radio. A high speed data link will be available in the near future by using a Collins Kineplex system to Antigua, then Pretoria and Ascension Island and then via AMR cable to Cape Canaveral.

3.4 MCC. -

3.4.1 Functions. - The MCC will perform the following functions.

3.4.1.1 Ground Forces Control. -

3.4.1.1.1 Network Control. - The Mission Control Center shall be responsible for network readiness, for exercising the network during pre-mission periods, for controlling the network during missions, and for the network debriefing on capsule-centered information. It shall prescribe the mode of operation if options are available. It will control the data editing devices relaying capsule information (whether these be men or machines). It shall provide target designation data. It shall control voice and command communication to the vehicle in the normal mode where ground stations act as a relay point.

3.4.2 Facilities. - The Mission Control Center is regarded as a central complex which contains and directs several major support facilities. These are briefly defined below. The term MCC will hereafter refer to the entire Mission Control Center Complex, and specific reference will be made to the center or function under discussion. The Mission Control Center will contain the following facilities as shown on Figure 11:

a. Operations Center: includes the key personnel as shown on Figure 12, data displays and communications needed to permit overall control of the entire Apollo Mission.

b. Computer Center: includes all major computational and data processing equipment needed to support the GOSS. These functions include trajectory, navigation and guidance problems, system exercise and checkout, mission planning and post-flight analysis.

c. Communication Center: the terminal point for all communications facilities supporting the GOSS network. Provides switching and patching capabilities between the MCC, LCC and all GOSS remote stations.

d. Recovery Control Center: contains all key personnel, displays, and communications for exercising tactical control over the DOD or other recovery forces.

e. Training and Simulation Center: contains all facilities for training Flight Crew and Flight Controller personnel. Provides for and directs mission simulations and other exercises to achieve and maintain personnel proficiency, formulate operational procedures, and integration of the entire GOSS network.

f. Houston Remote Station: will function as any normal remote GOSS Station, and provide inputs for MCC and network simulation and training.

g. Administrative Center: as required by MSC.

3.4.2.1 Operations Center. - The Operations Center shall consist of a Control Center and an In-Flight Evaluation and Diagnosis Center. The key controller personnel and the required equipments and displays will be located in the Control Center. Supporting equipments and personnel, other than the computer and communications terminal facilities, will be located in the In-Flight Evaluation and Diagnosis Center, and will provide detailed spacecraft systems monitoring and will furnish the Control Center with information when needed for contingency situations.

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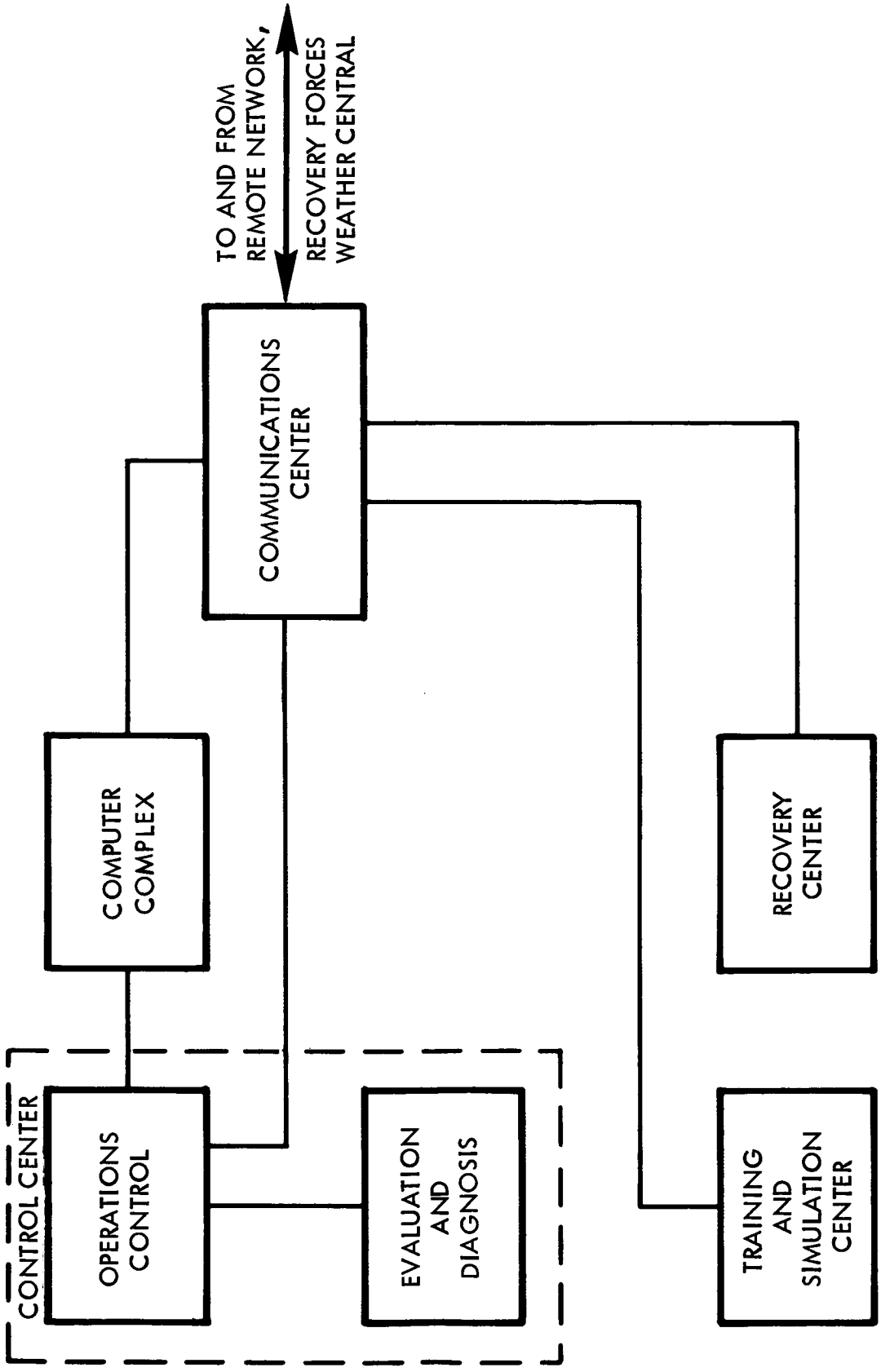

Figure 11. MCC Complex Block Diagram

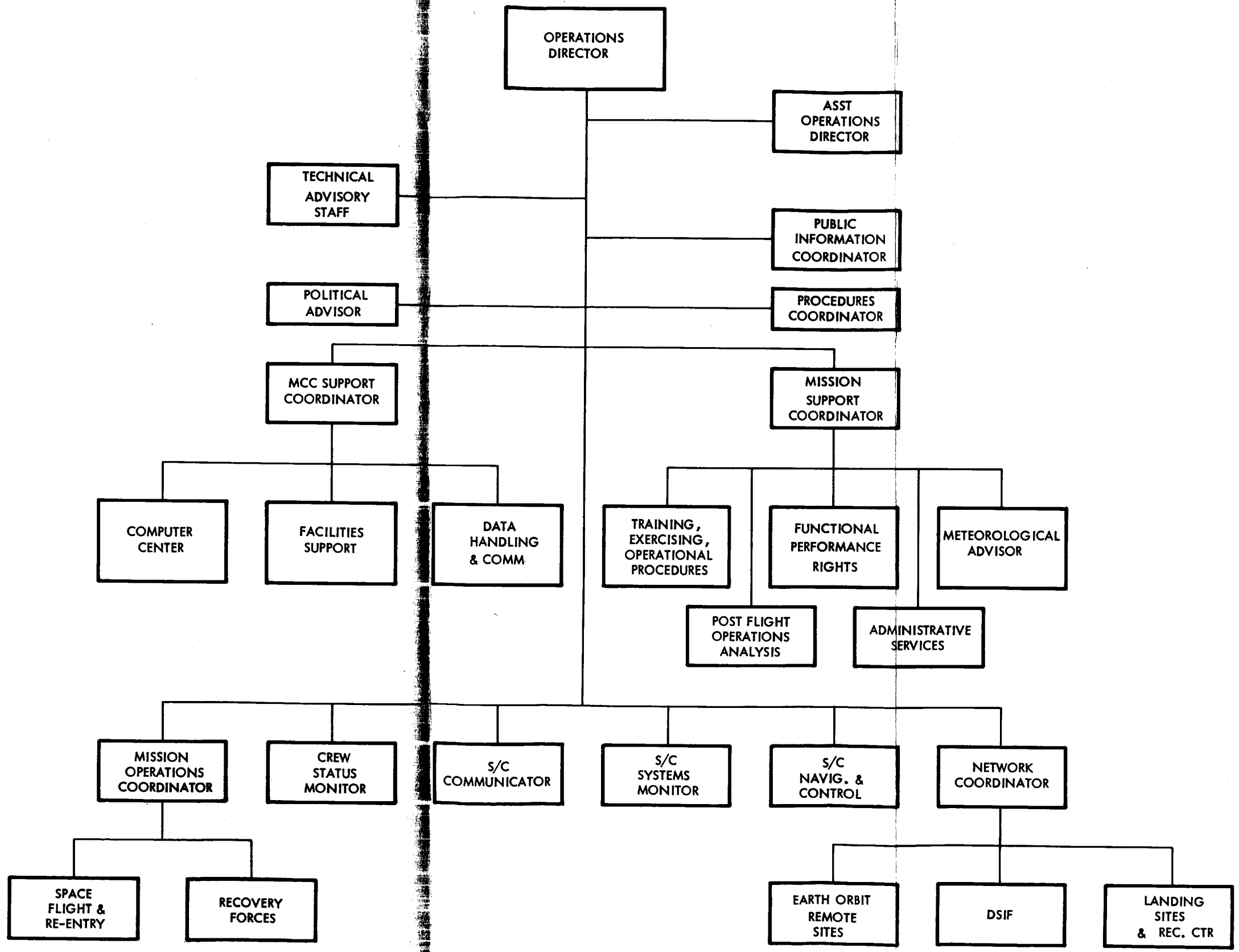

Figure 12. MCC Functional Organization

3.4.2.1.1 Wall and Console Displays. - To assure mission success adequate display facilities shall be provided at the MCC. The displays are divided into wall displays and consoles. Wall displays shall be located at the front of the control room and be of such size that their details be visible to an observer in any part of the room, and to observers in an adjacent public relations room.

Individual consoles shall be designed with human engineering aspects in mind to increase the efficiency of the operator. The consoles shall be flexible enough to accommodate any program or changes in the programs. The functions of the displays at MCC are to:

a. Inform operating personnel of the mission progress and aid in mission evaluation and alternate mission planning.

b. Monitor spacecraft crew status.

c. Monitor status spacecraft systems and subsystems

d. Monitor position of the spacecraft

e. Monitor status of the GOSS system and subsystem

3.4.2.1.1.1 Wall Displays. -

A. Spacecraft Position Display. The MCC shall have provisions to display the up-dated position of the spacecraft on a pictorial background. The mechanism of the background shall be such that various pictorial maps, flight paths, etc., may be rapidly moved in or out of the display scene to correspond with the progression of the spacecraft mission. The calculations for positioning of the spacecraft symbol and its imaginary impact point shall be done by computers. Also, the computer shall be capable of changing the scaling of the display for improved definition of certain mission events.

The pictorial presentation displayed can be of the following types:

a. The map covering Cape Canaveral and associated areas.

b. The map of the world with predicted and actual paths of the spacecraft.

c. Enlarged scales of primary, secondary and alternate landing areas.

d. Enlarged scale of injection area (projection of spacecraft on the earth).

e. Flight path between the earth and the moon.

f. Projection of the spacecraft symbol and its track on the world map.

B. Mission Event Status Display. The MCC shall provide for the display of mission events. This display can be in tabular form. The size and complexity of this display will depend upon the number of events which are to be displayed. The table can be updated manually or by a computer generating alphanumeric characters for the display. Provisions can also be made for recalling previous events. The following items shall be displayed:

a. Name of the event

b. Event in progress

c. Predicted time of commencement

d. Actual time of commencement

e. Duration of event

C. Communications Status Display. The status of the communications links between the remote stations and the MCC Communication Center shall be presented on the wall type display. Primary and alternate routes, station status, and other information necessary for successful direction of the point to point communications shall be included.

D. Graphical Displays. A projection display shall be provided to present telemetry trends, graphical plots and other related information. This display shall be driven by a computer, to integrate the types and quantities of information presented and to increase the display flexibility.

E. Recovery Forces Status Display. The status of the recovery forces shall be displayed in tabular form. The following information shall be included:

a. Name of the recovery force

b. Present position

c. Desired position

d. Mission assignment

e. Status condition

F. Weather Status. Prevailing weather conditions at the Launch Control Center, primary, secondary, and alternate landing areas shall be displayed on a wall type display.

G. Spacecraft Communication Status. Station spacecraft communications contacts shall be displayed on the wall type display. The following information shall be provided:

a. Identity of the station in contact with the spacecraft

b. Identity of the next station to make contact

c. Expected time of contact

d. Actual time of contact

e. Expected duration of contact

f. Time of contact loss.

3.4.2.1.1.2 Console Displays. -

A. Operations Control Console. An operations control console shall be provided to:

a. Monitor LCC operations during pre-launch and launch

b. Initiate abort procedures during mission emergency conditions

c. Control countdown procedures

B. Procedures Monitor Console. A procedures monitor console shall be provided to call out past or future events for presentation on the summary wall displays.

C. Launch Control/Surface Operations Console. A launch control/surface operations console shall be provided to:

a. Monitor mission phase event sequence

b. Monitor lunar surface operations

c. Display impact prediction area based on computer calculations

d. Request computer computations

e. Override computer decisions

f. Display time scales for mission events, (time to go, event initiation, event completion).

D. Flight Dynamics Console. A flight dynamics console shall be provided to:

a. Display acceleration, velocity and point in space for all phases of the mission

b. Display time scales for mission events

c. Indicate which mission can be accomplished successfully, based upon computer calculations

d. Request computer calculations

e. Override computer decisions

f. Provide space flight maneuver correction hard copy print out which shall indicate maneuver correction within the spacecraft's maneuvering capability for the mission that can be successfully accomplished according to mission objective priorities.

g. Plot velocity, accelerations versus point in space

F. Recovery Forces/Recovery Area Status Console. A recovery forces/recovery area status console shall be provided to:

a. Display recovery forces current status

b. Display recovery forces current area status

c. Provide deviation print out hard copy effecting recovery force, recovery areas status.

G. Spacecraft Communication Console. A spacecraft communication console shall be provided to display mission events sequences for all phases of the mission.

H. Spacecraft Crew Status Console. A spacecraft crew status console shall be provided to:

a. Display status conditions of each spacecraft crew member

b. Record important physiological data on strip chart recorder. for future reference.

I. Spacecraft Systems Status Console. A spacecraft systems status console shall be provided to:

a. Monitor spacecraft systems

b. Provide deviation print out of the spacecraft systems, indicating which system is deficient, time of deficiency, cause, and estimated time of correction.

J. Spacecraft Environmental Console. A spacecraft environmental console shall be provided to:

a. Monitor the environmental system status

b. Record vital environmental data for future reference.

K. Spacecraft Navigation and Control Console. A spacecraft navigation and control console shall be provided to:

a. Monitor the Navigation and Guidance System

b. Provide control deficiency hard copy print out.

3.4.2.2 Central Computer Complex. - The computer complex may contain the following requirements.

a. Two duplexed general purpose digital computers, hereafter identified as the central processors

b. A central processor director system

c. One off-line large scale digital computer

d. One off-line input/output computer

e. One trainer control and simulation computer

f. A communication interface system

Fig. 13 shows a basic block diagram of the central computer complex.

A. Central Processors. A pair of duplexed general purpose digital larger scale computers shall be used at the MCC to perform all computations and data processing required to support the Apollo mission. Both computers shall execute identical programs and accept identical inputs. During duplex operation, these computers shall solve internal test problems, compare answers, and present appropriate diagnostic information to a Central Processor Director system.

B. Central Processor Director System. This system shall provide the prime man-machine interface. It shall be able to display the operability of the two computer channels, provide for controlling both or either one of the duplex computers by overriding machine decisions and initiating alternate courses of action, interrogate the computers for timely information concerning the mission status or data flow, and initiate self checking routines for the Central Processors.

C. Off-line Large Scale Computer. This computer will be used as a back-up for the central processors. It will also be used for non-routine and non-real time computations tasks required in connection with the Apollo program.

D. Off-line Input/Output Processor. This processor will support the large scale computers in areas of non-routine, non-real time computations, data formating, and preparation of data for large scale computers; and will perform other computations not efficiently handled by the large machines.

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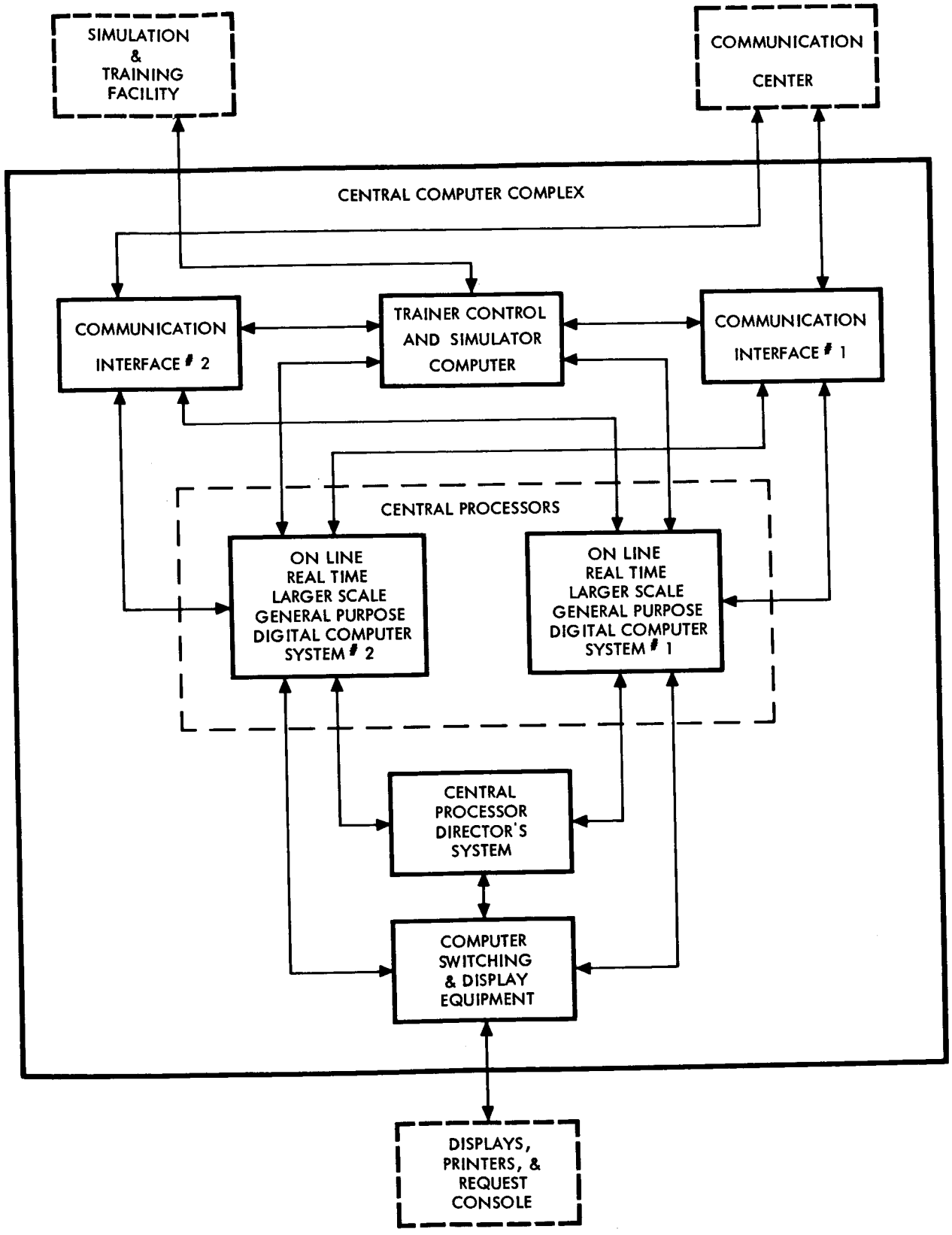
SIMULATION & TRAINING FACILITY
COMMUNICATION CENTER
CENTRAL COMPUTER COMPLEX
COMMUNICATION INTERFACE # 2
TRAINER CONTROL AND SIMULATOR COMPUTER
COMMUNICATION INTERFACE # 1
CENTRAL PROCESSORS
ON LINE REAL TIME LARGER SCALE GENERAL PURPOSE DIGITAL COMPUTER SYSTEM # 2
ON LINE REAL TIME LARGER SCALE GENERAL PURPOSE DIGITAL COMPUTER SYSTEM # 1
CENTRAL PROCESSOR DIRECTOR'S SYSTEM
COMPUTER SWITCHING & DISPLAY EQUIPMENT
DISPLAYS, PRINTERS, & REQUEST CONSOLE

Figure 13. Central Computer Complex

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E. Trainer Control and Simulation Computer. This computer shall have the capability of transmitting and receiving data to and from the communication equipment, the communication interface equipment, and the central processors. The trainer control and simulation computer will be required to have real time control via program interrupt function, plus a large capacity for handling on-line input-output units. It is also necessary for the trainer control and simulation computer to accept data from the communication tapes (magnetic and paper).

F. Communication Interface System. This equipment shall provide for transferring data between the MCC Communications Equipment and the central processors, the simulation equipment, and shall provide for storing and reading out data from the tape storage. The Communication Interface System shall consist of a Data Communication Output Selector and a Data Communication Input Buffer. Both of these systems shall be controlled by the central processor's executive program. The Data Communications Output Selector shall be capable of performing the following functions:

Converting parallel digital data to serial data, assuring compatibility between individual data rates and their tolerances, assisting the central processors in performing computations during periods of peak loads, and selecting the output transmitter to be used when transferring data to the remote station. The Data Communication Input Buffer shall be capable of converting serial transmitted information to parallel digital data for use by the central processors, assigning priorities to input data as a function of the mission phase, assuring compatibility between individual data rates and their tolerances, providing alternate inputs for reliability, and assisting the Central Processors in performing computations during periods of peak loads.

3.4.2.2.1 Computer Interfaces. - All input and output equipments shall be duplicated.

The computer complex shall be capable of handling inputs from the following data sources:

a. Teletype circuits

b. High speed digital data circuits

c. Magnetic tapes

d. Punched cards

e. Keyboards, pushbuttons and other input devices from control consoles.

The computer complex shall be capable of feeding data to the following users:

a. Teletype circuits

b. High speed digital circuits

c. Magnetic tapes

d. Displays for flight controllers

e. Suitable digital-analog converters or other buffering equipment.

3.4.2.2.2 Computations in Support of the Spacecraft. - The following input information shall be assembled in proper computer format prior to launching and stored in the computer:

a. Maneuver capabilities of the spacecraft

b. Program for the earth-moon spatial relationship computations with provisions for the launch-time inputs: launch azimuth and time of launch

c. Atmospheric and solar weather information—updated at intervals.

d. Specifications of the mission objectives and trajectories

e. Lists pertaining to the spacecraft status and capabilities, particularly with regard to predicted rates of propellant consumption and total propellant load

f. Permissible earth orbit and lunar trajectory tolerances within which the mission can be successfully accomplished

g. Emergency abort procedures to be specified for each mission

h. Normal orbit and other trajectories planned for the mission prior to launch.

A. Computations for Earth-Orbital and Near-Earth Operations. In the pre-launch phase the computer shall generate the nominal orbit for the intended mission which shall be updated up to launch time to include the actual launch azimuth and the perturbing effects of atmospheric weather, in addition to all other factors which may affect the orbit. During the launch or boost phase, the computer shall perform all calculations and data analysis required by the flight controllers for the abort command, if necessary. Subsequent to launching, initial tracking data from the AMR facility shall be used to compute corrections required to achieve the planned orbit and transmit them to the spacecraft. The computer shall test for abort conditions. If emergency abort is not imminent, the computer shall calculate re-entry conditions for landing at either the primary or secondary landing stations. If abort is imminent, the computer shall determine the emergency impact point and provide all relevant information to the GOSS.

Preliminary Computer Functional Flow chart for spacecraft and GOSS Support of Earth Orbital and Near Earth missions is presented on Fig. 14. The chart shows various principal computations and decisions performed by computer and flow of information to the displays and consoles.

B. Rendezvous. Computations shall be performed in pre-launch phase to determine the nominal orbit required of any module intended for rendezvous with the command module. In the launch phase, tracking data for the rendezvous module, in conjunction with orbital data of the command module, shall be used to compute navigation and guidance data to successfully accomplish the rendezvous maneuver.

C. Lunar Operations

Pre-Launch Phase. Computations shall be similar to those of the earth-orbital mission except that lunar trajectories for the intended mission shall be computed. Nominal lunar injection point, lunar orbits, lunar landings, and return-to-earth trajectories shall be computed as required by the intended mission and stored for future use.

In-Flight Phase. Earth-orbital computations are duplicated for the earth-parking orbits. The lunar injection point shall be computed using earth-moon spatial relationship data in addition to launch data. The computer shall proceed as in the orbital case to determine lunar trajectory corrections considering such things as the maneuver capability and fuel capacity of the module. If abort is

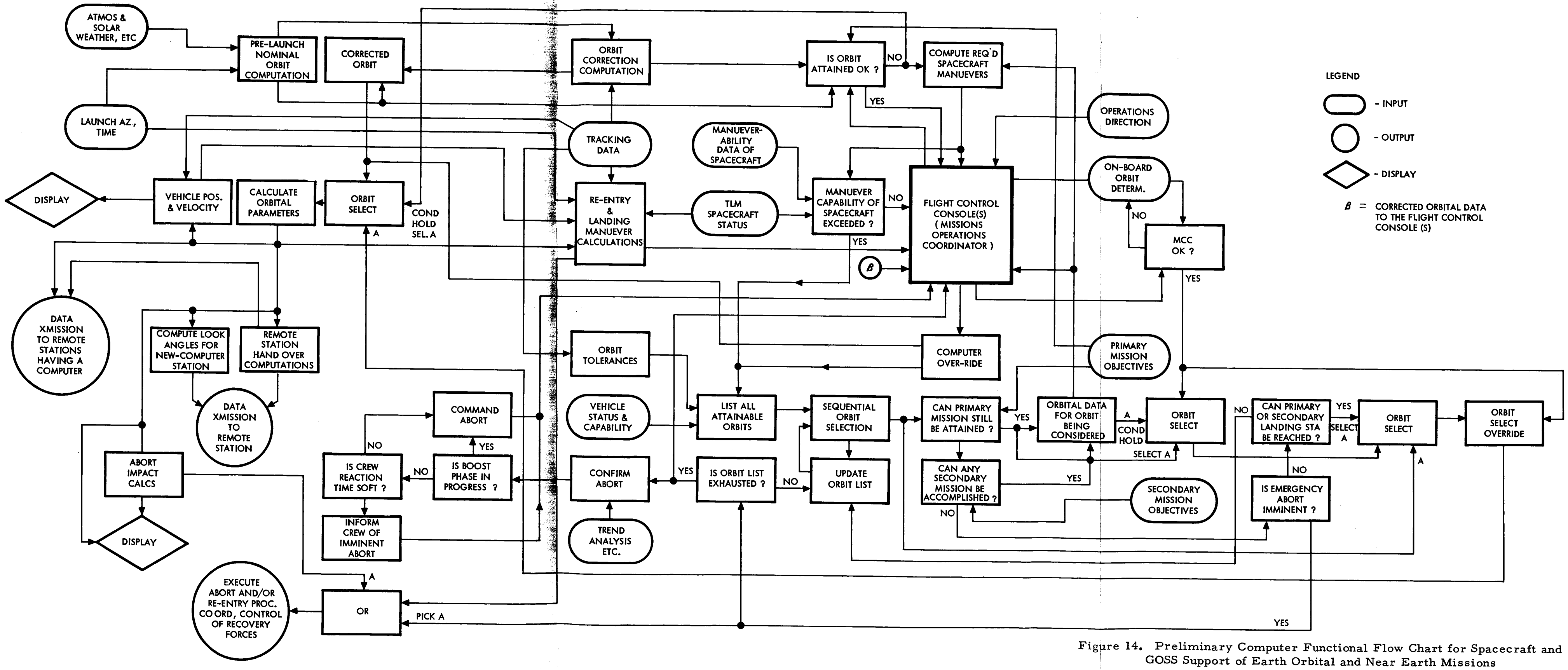

Figure 14. Preliminary Computer Functional Flow Chart for Spacecraft and GOSS Support of Earth Orbital and Near Earth Missions

imminent, the computer shall compute the guidance maneuvers required to return to earth, re-enter, and land at a designated landing station, if possible. Otherwise, the computer shall initiate data for recovery force redeployment to the expected impact point. If abort is not imminent and the intended mission cannot be completed, the computer shall determine what missions can be accomplished and compute appropriate navigation and guidance information according to a priority list of secondary objectives.

3.4.2.2.3 Computation in Support of the GOSS. - The MCC computer shall perform the following computations in support of the GOSS mission:

A. Recovery Force Redeployment. The computer shall assess the capabilities of the recovery forces and determine the optimum redeployment of these forces to minimize recovery time.

B. Remote Station Target Designation Data. The MCC computer shall supply remote tracking and telemetry stations with target acquisition data. The type of data transmitted depends on the availability of communications to and computational facilities at the remote stations. The following types of designation data shall be computed as required:

1. Orbital elements for stations equipped with an appropriate digital computer

2. Look angles in real-time where high speed digital data links are available

3. Look angles in non-real time where communications are limited to teletype

C. Generation of Display Information

Positional Information Display. The MCC computer shall compute data for display at various locations within the MCC and shall include the following:

1. Present position of the spacecraft.

2. Predicted positions of the spacecraft, depending on the phase of the mission. These may include information such as predicted impact points, and insertion points.

Digital Read-Outs and On/Off Data. The following users will be presented with on/off type of data from the computer:

1. Crew status monitor
2. Spacecraft system monitor
3. Navigation system monitor
4. Recovery forces monitor
5. Launch Control/Surface Operations Console

These data shall be presented to the display whenever a change occurs in the information. In addition, the data shall also be repeated to the displays at regular, but relatively infrequent intervals to protect against erroneous changes due to transients.

Control Interface Between Displays and Computers. Facilities shall be provided to give certain operating personnel access to the computer to perform special operations relating to displays. These shall include:

1. Request for changes in scale factors for devices such as the wall display and plotting boards.
2. Request a repeat of on/off and digital read-outs to confirm questionable items.
3. Request special computations; for example, to back up or verify data in the spacecraft, if such computations are not performed at scheduled intervals.
4. Call up detailed telemetry information, or special items, from the local or remote computers in response to observing abnormal conditions.

3.4.2.2.4 Data Processing by the MCC Computational Facility. -

A. Input Data Processing. The computer system shall be capable of accepting data from the incoming communications facilities, from local displays and control consoles and from magnetic tapes, and shall do the following:

1. Perform error checks and error corrections, where applicable.

2. Convert the incoming data to a format that is usable by the program, including the insertion of needed identifying information where required.

3. Convert coordinates or units to make the input quantities compatible with the requirements of the program mathematics.

4. Execute elementary computations on incoming data: for example, in the case of telemetry, establishing trends, or converting differential measurements to absolute measurements.

5. Edit data for reasonableness to exclude bad data points.

B. Output Data Processing. The computer shall be capable of selecting appropriate data from the memory and condition these data for output devices. It shall perform the following types of functions:

1. Select the appropriate data and perform coordinate conversions, units conversions, and scaling operations as required to convert the information to the form acceptable by the user.

2. Present the information to the various users, including such as teletype, digital data links, digital to analog converters, tapes. Presentation in this context is to be interpreted as meaning the arrangement of the appropriate bit configuration, as well as the insertion of auxiliary information where required.

3. Format addresses for outgoing messages, identify special data for historical recordings, change factors in display data.

4. Insert error correction or error detection data, where required.

C. Executive Program Control. The internal operation of the computer will be controlled by the central processor director systems. The following tasks will be performed by this program:

1. It shall cause the proper programs to be read into core memory as the phases of the mission progress and the computational requirements change.

2. It shall determine the status of the GOSS network as the mission progresses and schedule the transmission of designation data to remote stations when the stations require them, when the communications channels are open.

3. It shall control the priorities of all input-output channels and computations.

4. It shall schedule the periodic initiation of system checkout functions to verify the operability of the communication networks and of the remote stations.

5. It shall determine, based on the phase of the mission, the permissibility of conducting preventive maintenance on one of the computers.

D. Historical Data Recording. Sufficient data recording will be provided at the MCC to permit a thorough post-flight data analysis to be performed. In general, the following data shall be recorded:

1. All incoming messages

2. All outgoing messages

3. All information between the computer and the displays which is not otherwise permanently recorded.

4. All computer malfunctions

5. Decisions made initially by the computer which affect the execution of the mission. Items included here are such things as results of insertion and injection computations and data leading to a decision to abort.

6. All equipment and status information.

3.4.2.3 Recovery Center. - The primary Recovery Control Center (RCC) shall be established in the Mission Control Center at Houston. The RCC, in close cooperation with the MCC, shall perform the following functions:

a. Maintain the status of all recovery forces assigned to the Apollo mission.

b. Advise the Flight Director of the recovery force status, and be prepared to recommend alternate landing sites on the basis of weather and time to retrieval.

c. Advise the recovery force of the mission status, probable landing point, crew status, and deploy the force accordingly.

d. Delegate authority to remote GOSS stations functioning as alternate Recovery Control Centers when the situation warrants.

e. Exercise tactical control over the recovery forces at all times, using the DOD or GOSS communication links as required.

3.4.2.4 The Houston Remote Station. - The Houston remote station and the MCC shall have the capability to be a central area used for operator training. A spacecraft simulator will be provided in the vicinity of the MCC. The MCC and the Houston remote station shall be capable of integrating with this simulator and other simulation equipment to synthesize a complete mission for training of operating personnel. In addition, it will be used to develop and improve the remote station operational procedures and also evaluate equipment to be incorporated later in the GOSS network.

3.4.2.5 MCC Operability Verification, Exercise, and Checkout Requirements. - The MCC shall have simulation equipments for performing the following tasks:

a. Verification of unit, equipment, station, and network operability

b. Realistic equipment, station, and network exercise, includint the operating personne.

c. Personnel training

d. Procedures development

e. Checkout as an aid to maintenance

f. Decision making to switch to standby units

g. Simulating the spacecraft and remote station interfaces

h. Simulating data and communications from and to the remote stations

i. Confidence tests

Means shall be provided for simulating data for both normal and abnormal Apollo missions. The equipment design shall be adaptable to variations in the GOSS network configuration and specifications, and to changes in operating procedures and mission goals: and expandable to accommodate additions to remote station and control center equipment complements. The existing simulation, checkout and test equipment shall be used whenever feasible.

3.4.2.5.1 Operational Verification During Actual Missions. - The GOSS simulation equipment shall provide positive means for precluding the entering of simulated or other extraneous inputs into any circuit or equipment during actual missions. However, it shall be possible to perform operability verification tests during actual missions at the specific direction of the mission operations director. The simulation equipment may be utilized to dynamically monitor the center and remote station equipment operation during actual missions where such monitoring does not interfere with GOSS operational requirements.

3.4.2.5.2 Demonstration and Acceptance Test Simulation. - The MCC verification, exercise, and checkout equipments shall be designed and implemented for performing acceptance tests and operational capability

demonstrations for individual equipments, stations, the MCC, and the GOSS network.

3.4.2.5.3 Operability Verification. - The Apollo GOSS simulation equipment shall be capable of verifying the operability of individual equipments at a station or center, stations as functional units, and the complete GOSS network.

The simulation equipment shall provide means for rapidly determining the overall operability of the MCC and of each subsystem at the MCC. The tests shall preferably be performed semiautomatically and the results shall be displayed to all Apollo personnel directly concerned with mission operations. The tests shall be performed by introducing accurately controlled test signals and data into the operational equipment that is to be verified. The overall output shall be compared with the predetermined required outputs. Specific provision shall be made for verifying the overall operability of the communications center, the computation center, and the Apollo mission displays. To perform this verification, the simulation equipment shall provide for the simulation of data inputs to the MCC and Houston remote station from any part of the GOSS network. The equipment shall provide for observing both actual and simulated outputs to the stations of the GOSS network. The MCC simulation equipment shall provide means for verifying operational compatibility between the GOSS and the Apollo spacecraft through mutual exercises.

3.4.2.5.4 MCC Exercise Requirements. - An exercise shall be any simulated mission designed for practice and improvement of operational and procedural functions. The simulation equipment shall provide means for exercising both equipment and personnel.

Provision shall be made for individual exercise of single equipments and personnel, for exercise of complete station or center equipment and personnel, and for integrated exercise of the complete GOSS network or of a sub-set of GOSS stations together with the MCC.

The MCC simulation equipment shall provide means for exercising the MCC equipment and personnel. The simulation equipment shall be adaptable to a wide variety of simulated Apollo missions, and shall be capable of simulating deviations from desired missions, equipment malfunctions, and abnormal aeromedical data. The simulation equipment shall provide for simulation of the Apollo spacecraft and integration of an Apollo crew trainer into the exercises. The MCC simulation equipment shall be capable of simulating the remote station network and, inaddition, shall provide for the inclusion of some or all of the remote stations in simulated missions. The MCC simulation equipment shall be designed to provide the maximum practical realism for personnel training, personnel proficiency maintenance,

and the development of operating procedures. To meet these requirements, the MCC simulation equipment shall include provisions for the simulation of remote station telemetry data, radar data, block-house event data, booster data, and teletype as well as voice communications with remote stations. The simulation equipment shall provide for the introduction of noise into the data links, for controlled degradation of signals, and for the introduction of simulated malfunctions.

The MCC simulation equipment shall be integrated with the Houston Remote Station simulation equipment to maximize realism during exercises and to provide a means for simulating other stations for integration with the Houston station. This integration shall be specifically designed to provide for exercises and procedure development drills that include astronaut training in an Apollo crew trainer. This integration shall also be designed to facilitate the development of optimum procedures, techniques, and equipment for the GOSS network and the GOSS-spacecraft interface.

3.4.2.5.5 MCC Checkout Requirements. - The GOSS simulation equipment at the MCC and at the remote stations shall be designed to serve as an aid to maintenance. The basic objective shall be to rapidly determine the location of any existing equipment malfunctions.

The MCC simulation equipment shall provide means for rapidly checking all station operational equipment, to determine if it is within tolerance for proper operation within specifications. It is preferable that this function be performed semiautomatically. The tests shall be performed by introducing controlled signals into the MCC equipments and comparing the equipment output with predetermined values. The comparison shall be capable of indicating equipment failure and at least one degree of equipment functional deterioration. Means shall be provided for checkout of both analog and digital systems.

The results of the checkout test shall be displayed to personnel at the MCC who are directly concerned with mission operations or equipment maintenance. The results shall also be reduced to hard copy.

3.4.2.5.6 MCC Simulation Requirements. - The simulation equipment at the GOSS remote stations and the MCC shall support the requirements for operability verification, exercise, and checkout. This section covers the types of data to be simulated:

A. Data to MCC. The MCC simulation equipment (Figure 15) shall be capable of simulating the following categories of data received at the center:

   (a) Spacecraft crew aeromedical data

   (b) Spacecraft systems and MCC generated data

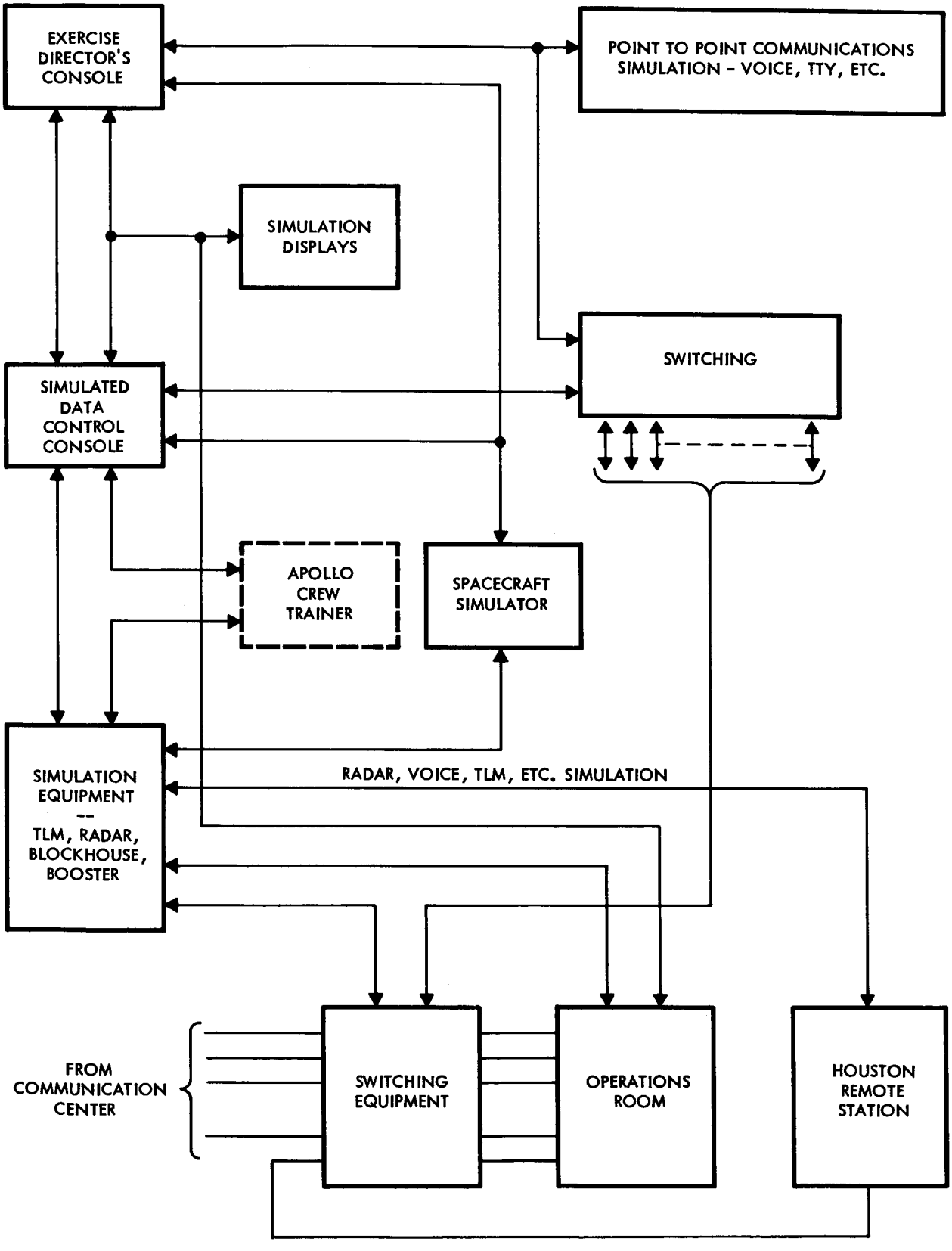

Figure 15. MCC-Houston Simulation System

c. Spacecraft environmental data

d. Guidance, navigation, and control systems data

e. Spacecraft voice transmissions

f. Network communications

g. Weather and space environment data

h. Recovery force status data

i Tracking data

j. GOSS status data

k. Mission profile data

l. Countdown status data

B. Data from MCC. The MCC simulation equipment shall provide means for accepting, checking, and simulating responses for the following categories of output data:

a. Voice to the spacecraft

b. Spacecraft commands (R & D only)

c. Digital data to GOSS remote stations

d. Voice to GOSS remote stations

e. Crew status and impact predictions to recovery forces

f. Acquisition data to remote stations

g. Emergency command and control signals to the spacecraft (R & D only)

3.4.2.5.7 Data Simulation Requirements. - The MCC simulation equipment shall simulate digital data received at the center in its normal form. The equipment shall provide for the introduction of noise and for the variation of signal over at least the full range of acceptable parameters. Provision shall be made to allow unrestricted choice of the information simulated.

The MCC simulation equipment shall provide means for accepting center digital data output and for the generation of appropriate responses.

3.4.2.5.8 Communications Simulation Requirements. - The MCC simulation equipment shall provide means for simulating communications with the remote stations.

The simulation equipment shall provide voice circuits and instruments over which communications with remote sites may be simulated. There shall be provisions for the introduction of noise and for the controlled simulated degradation of these circuits.

3.4.2.6 Communication Center. - The preliminary configuration of the communication center is shown in Figure 16. The communication center shall have the capability of receiving voice, teletype, high-speed data, and television signals from the GOSS stations and other supporting facilities and routing them to the proper destination in the MCC complex. Since there is a requirement for the MCC to direct the mission from lift-off, it is desirable to monitor by television the countdown progress, launch facilities, and the booster/spacecraft assembly at the launch control center. The communication center shall be capable of receiving and relaying the spacecraft television signals from the LCC during the launch and from the DSIF station at Goldstone during lunar missions and relaying them to MCC.

The communication center shall transmit messages and data originating at MCC to the desired remote stations and to the LCC. It also shall be capable of receiving messages from remote stations and retransmitting these messages to all other stations and centers in the network (for example, each station mission summary report is sent to all other stations and centers).

All the teletype messages shall be recorded on paper tape for future analysis and/or retransmission. High-speed data shall be recorded on a digital magnetic tape recorder for future reference and/or retransmission to the GOSS network.

All voice information routed through the communication center shall be recorded on the magnetic tape for the following functions:

a. Mission analysis

b. Debriefing

c. Public information

d. Retransmission to the GOSS network

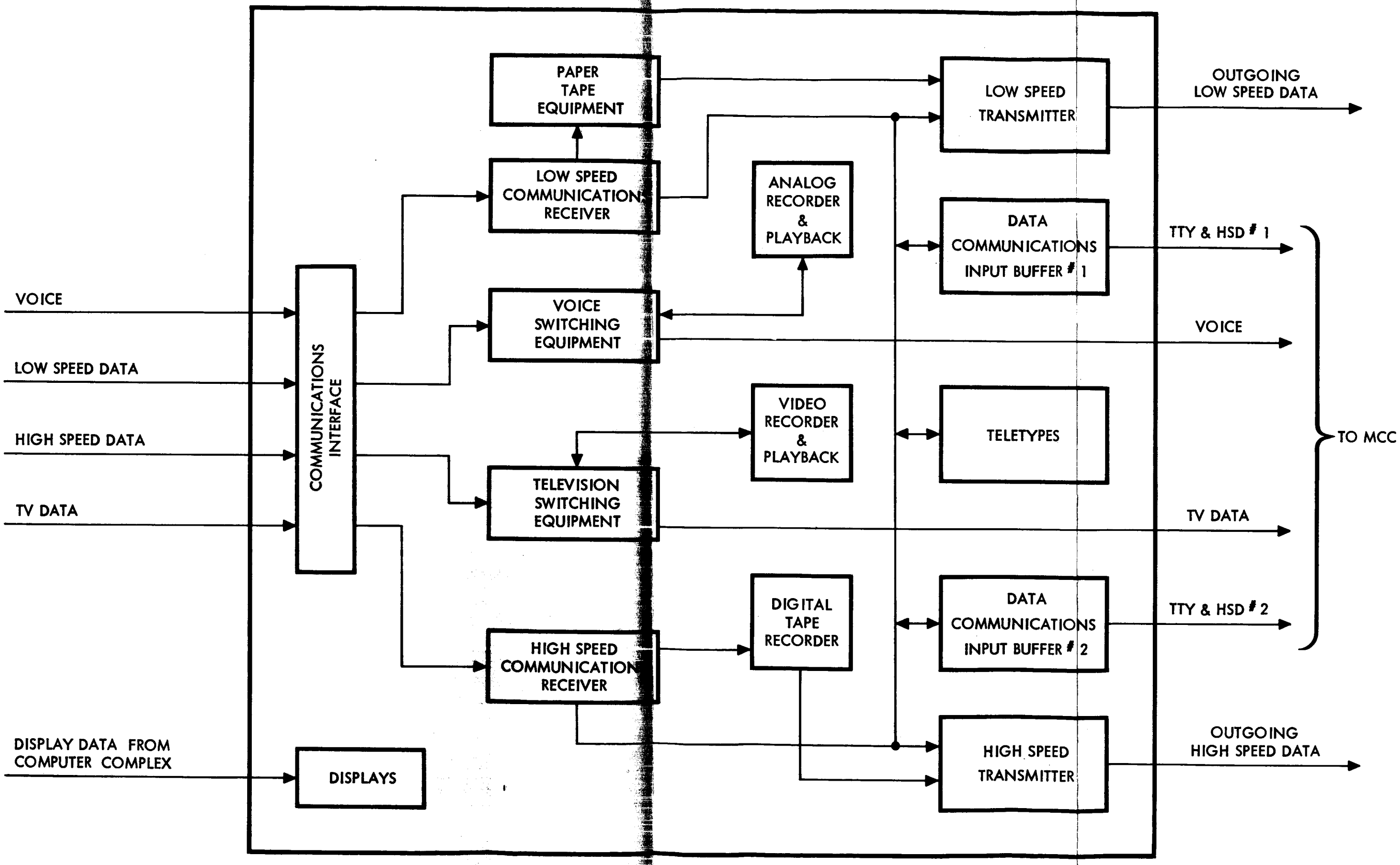

Figure 16. Communications Center

The communication center shall be able to handle priority data according to previously established procedures and assignments.

It shall be able to detect and correct errors in the incoming messages and encode outgoing messages according to the prescribed error correction and detection codes and procedures. Adequate display and control capabilities shall be provided in the communication center. A wall display presenting communications routings is desirable. Routes of stations in contact shall be indicated. Alternate routings also shall be indicated.

A communication control and maintenance console shall be provided at the communication center. The console will display the status of equipment at the communication center. Controls shall be provided to direct operation of the communication center and remote stations routings.

3.4.3 Organization. - The functional organization of the MCC is shown in Figure 11.

3.4.3.1 The Operations Director shall:

a. Exercise management decisions regarding emergency conditions during mission operations

b. Resolve major problems in operations

c. Supervise overall Apollo operations

d. Establish doctrines and make policy decisions

e. Exercise decisions concerning continuation of mission under certain marginal and system failure conditions

f. Delegate authority over and above standard alternate procedures during certain emergency conditions

3.4.3.2 The Assistant Operations Director shall perform the following function:

a. Assist the Operations Director in performing his functions

b. Represent the Operations Director in his absence

3.4.3.3 Staff. - The following staff members shall report to the Operations Director or the Assistant Operations Director.

3.4.3.3.1 The Technical Advisory Staff shall advise and assist the Operations Director as required in connection with special problems relating to the overall mission.

3.4.3.3.2 The Procedures Coordinator shall:

a. Monitor all operational procedures and advise on procedural changes of the GOSS

b. Insure that procedural functions are exercised by controllers and agencies in the proper time cycle and provide and alternate time cycle if the primary one is not met.

3.4.3.3.3 The Political Advisor shall advise and assist the Operations Director as required in areas involving relationships with other countries.

3.4.3.3.4 The Public Information Coordinator shall:

a. Prepare and issue news releases.

b. Authorize release of information to public.

3.4.3.4 The MCC Support Control Coordinator shall:

a. Coordinate operation, maintenance, or modification of all MCC data processing and display facilities.

b. Coordinate maintenance or modification for MCC support facilities, such as power generator, and the air conditioning system.

c. Consult with specialists regarding equipment deficiencies.

d. Advise the Operations Director of serious equipment malfunctions.

3.4.3.4.1 The Computer Facility Monitor shall:

a. Monitor computer facilities and associated peripheral equipment.

b. Evaluate and analyze malfunctions associated with the computer facilities.

c. Inform MCC Support Control Coordinator of malfunctions of computers and associated peripheral equipment.

d. Direct scheduled and unscheduled maintenance on computer and associated equipment.

3.4.3.4.2 The Facilities Support Monitor shall:

a. Monitor all facilities associated with support and maintenance of MCC.

b. Evaluate and analyze malfunctions within support facilities.

c. Inform MCC Support Control Coordinator of malfunctions associated with support facilities.

d. Direct facilities maintenance and repair as required.

3.4.3.4.3 The Data Handling and Communications Facility Monitor shall:

a. Monitor message input/output handling capability and intra-MCC communications.

b. Evaluate and analyze deterioration in data handling and communications capability.

c. Inform MCC Support Control Coordinator of deteriorated conditions and recommend corrective action.

d. Implement corrective action.

3.4.3.5 The Mission Support Coordinator shall:

a. Coordinate training exercises and development of operational procedures in association with the Procedures Coordinator to conform with operational mission requirements.

b. Exercise control over MCC administrative functions.

3.4.3.5.1 The Training, Exercising and Operational Procedures Coordinator shall:

a. Establish operational procedures for conducting simulated mission exercises.

b. Conduct training programs for establishing and maintaining crew and ground operations personnel proficiency.

c. Assist in establishing procedures for the entire mission operation.

3.4.3.5.2 The Postflight Operations Analysis Group shall:

a. Conduct postflight analysis of mission operation.

b. Provide recommendations for more efficient GOSS performance during subsequent missions.

3.4.3.5.3 The Functional Performance Requirements Group shall:

a. Establish and modify job performance requirements.

b. Establish and modify GOSS requirements.

3.4.3.5.4 The Administrative Services Staff shall:

a. Maintain records of message input/output which are not processed by the computer.

b. Maintain personnel records.

c. Maintain inventory records of facilities.

d. Provide other administrative support where necessary

3.4.3.5.5 The Meteorological Advisor shall:

a. Make recommendations relating to mission planning which involve meteorological aspects of missions.

b. Maintain and provide to the GOSS information on landing station weather.

3.4.3.6 The Missions Operations Coordinator shall:

a. Monitor overall countdown and launch operations

b. Monitor overall progress of flight mission and crew inflight tests

c. Coordinate with recovery forces, launch control, and spacecraft monitors to determine whether environmental, range status, or other conditions will prevent launch or such as in the case of initiation of re-entry, whether the spacecraft life support system would tolerate a delay.

d. Advise recovery forces of spacecraft re-entry landing predictions

e. Coordinate with the spacecraft communicator concerning problems affecting mission progress

f. Advise the Operations Director of emergency conditions existing in launch, space, or recovery forces

3.4.3.6.1 The Space Flight and Re-entry Monitor shall:

a. Monitor each phase of the mission flight profile

b. Consult periodically with meteorological advisors

c. Evaluate and analyze all flight mission events which deviate from those which are expected.

d. Consult with spacecraft specialists regarding performance of the spacecraft.

e. Inform the Mission Operations Coordinator of unexpected situations and provide recommendations for corrective action.

3.4.3.6.2 The Recovery Forces Monitor shall:

a. Monitor recovery forces status, and advise of predicted launch time, landing time and specify landing regions.

b. Inform the Missions Operations Coordinator concerning recovery forces status and location deviations.

c. Consult periodically with the Meteorological Advisor.

3.4.3.7 The Spacecraft Communicator shall:

a. Coordinate all scheduled and unscheduled voice contacts with the spacecraft.

b. Provide diagnostic support to spacecraft concerning equipment and crew failures.

c. Provide and forward alternative operating procedures to the spacecraft crew in event of spacecraft malfunctions.

d. Provide the spacecraft crew with earth based data concerning information on weather and space environment.

e. Provide the spacecraft crew with information on status of forces in the recovery area.

f. Participate in command and control of spacecraft during emergency operations when delegated responsibility by the operations director.

3.4.3.8 The Crew Status Monitor shall:

a. Monitor crew aeromedical status during all phases of the mission.

b. Evaluate and analyze deficiencies relative to biomedical status.

c. Inform the Spacecraft Communicator of biomedical deficiencies and recommend corrective action.

3.4.3.9 The Spacecraft Systems Status Monitors shall:

a. Monitor the parameters associated with the S/C electrical, instrumentation, propulsion and communications systems.

b. Observe the performance of these sub-systems, analyze the trend of the data, and the probability of degradation or malfunction.

c. Inform the Flight Director of malfunction situations and recommend corrective actions.

3.4.3.10 The Spacecraft Navigation and Control Monitor shall:

a. Monitor the parameters presented on the Navigation and Guidance Panel, and the Orientation Control System Panel.

b. Observe the performance of the S/C equipments within the sub-system, and the interface between the Navigation and Control and other S/C sub-systems.

c. Inform the Flight Director of any deviations or malfunctions affecting the Mission and recommend corrective action.

3.4.3.11 The Spacecraft Environmental Control System Monitor shall perform essentially the same function as the monitors under 3.4.3.9 and 3.4.3.10 with the exceptions imposed by the system design.

3.4.3.12 The Network Coordinator shall:

a. Monitor station network status conditions.

b. Relay alternate procedures as directed by Procedures Coordinator.

c. Provide backup voice acquisition data to network stations in the event of teletype failure.

d. Provide flight and operations mission status to network stations.

e. Relay re-entry prediction information to those stations participating in the recovery forces.

f. Maintain central operational control of network communications.

g. Advise the Operations Director of emergency network conditions.

3.4.3.13 The Launch Control/Surface Operations Monitor shall:

a. Monitor preparation and checkout of the spacecraft-booster combination.
b. Monitor conduct of the countdown

3.4.4 Information Requirements

Tables III, IV, V and VI list typical information requirements associated, respectively, with the Support Coordination Mission Operations Coordination, Spacecraft and Crew Monitoring, and Network Coordination Functions.

Table III. Information Requirements for MCC Support Coordination Functions

Equipment Systems	Status			
	Go/No Go	Cause	Time of Failure	Expected Down time
Computers and other data reduction equipment	x x	x x	x x	x x
Facilities				
Power supplies	x	x	x	x
Air conditioning	x	x	x	x
Data Handling & Communications	x	x	x	x
Displays	x	x	x	x
Intercom System	x	x	x	x
PBX	x	x	x	x
TWX	x	x	x	x
Printers	x	x	x	x
Timing Equipment	x	x	x	x
Switching Equipment	x	x	x	x

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Table IV. Information Requirements for Mission Operations Coordination Functions

MISSION PHASE	INFORMATION REQUIRED															
	Predicted Time-to-Go	Time of Event	Elapsed Time	Boost Engine Thrust	Posigrade Thrust	Retro Thrust	"G" Loads	Velocity	Acceleration	Attitude	Desired Point in Space	Actual Point in Space	Predicted Impact Point	Predicted Reentry Point	Recovery Forces Status	Predicted Meteorological Conditions
I. EARTH ORBIT MISSIONS																
Prelaunch	x	x	x												x	x
Lift off to End of Boost	x	x	x	x			x	x	x	x	x	x	x			
Coast to Orbital Insertion	x	x	x		x		x	x	x	x	x	x	x		x	x
Park Orbit	x	x	x					x		x	x	x	x			
Reentry														x	x	x
Engine Start/Stop	x	x	x			x	x		x	x	x	x	x			
Trajectory	x	x	x				x		x	x	x	x	x			
Chute Deployment	x	x	x				x		x		x	x	x			
Recovery	x	x	x												x	x
Radio Beacon	x	x	x								x[1]	x[1]				
II. LUNAR ORBIT & LANDING MISSIONS																
Docking Operations																
Contact	x	x	x							x	x	x				
Operation	x	x	x							x	x	x				
Separation	x	x	x							x	x	x				
Lunar Trajectory Injection										x	x	x				x
Engine Restart	x	x	x				x		x	x	x	x				
Guidance and Translunar Flight	x	x	x							x	x	x				x
Lunar Orbit	x	x	x			x				x						
Retro Engine Start/Stop	x	x	x				x		x	x	x	x				x
Lunar Landing	x	x	x				x		x	x			x			x
Contact	x	x	x				x			x	x[2]	x[2]				
Lunar Surface Operations	x	x	x													
Lunar Launch	x	x	x	x			x		x	x						
Trans Earth Flight	x	x	x								x	x				x
Earth Reentry	x	x	x				x		x	x	x	x	x	x	x	x
Recovery	x	x	x								x[1]	x[1]			x	x

1 Desired Point on Earth Surface
2 Desired Point on Lunar Surface

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Table V. Information Requirements for Spacecraft and Crew Monitoring Function

Items to be Monitored	Monitoring Schedule and Method of Transmission					
	During Special Phases (eg. Launch, Reentry)		Preestablished Schedule (Periodic/aperiodic)		Critical Threshold Exceeded	
	TLM	VOICE	TLM	VOICE	TLM	VOICE
I. CREW STATUS						
1. Electrocardiogram (EKG)	x		x			
2. Blood pressure	x		x			
3. Heartbeat	x		x			
4. Respiration	x		x			
5. O_2 comsumption			x			
6. CO_2 output			x			
7. Body temperature	x		x			
8. Suit temperature			x			
9. Radiation dosage			x	x	x	x
10. Personal observation of physiological and emotional status of self and mates		x		x		x
11. Special physiological tests BMR Urine analysis Water loss EKG						

Table V. (Cont.)

Items to be Monitored	Monitoring Schedule and Method of Transmission					
	During Special Phases (eg. Launch, Reentry)		Preestablished Schedule (Periodic/aperiodic)		Critical Threshold Exceeded	
	TLM	VOICE	TLM	VOICE	TLM	VOICE
II. SPACECRAFT SYSTEMS AND ENVIRONMENT						
1. Food and water				x		
2. Sound levels	x	x	x	x	x	x
3. Vibration attenuation	x	x	x	x	x	x
4. Environmental control Sys.						
O_2/N status			x			
Cabin pressure			x			
Relative humidity			x			
CO_2 partial pressure			x			
Temperature regulation			x			
Atmospheric conditioning Sys.			x			
5. Escape System			x			
6. Couch/restraint system				x		
7. Space flight suit status	x					
8. Waste disposal system				x		
9. Power supplies (AC/DC)			x	x		
10. Equipment Temp regulation			x	x		
11. Spacecraft inner/outer skin temperature	x	x	x	x		

Table V. (Cont.)

Items to be Monitored	Monitoring Schedule and Method of Transmission					
	During Special Phases (eg. Launch, Reentry)		Preestablished Schedule (Periodic/aperiodic)		Critical Threshold Exceeded	
	TLM	VOICE	TLM	VOICE	TLM	VOICE
II. SPACECRAFT SYSTEMS AND ENVIRONMENT						
12. Spacecraft structure integrity	x	x	x	x		
13. Particulate removal (debris trap)			x	x		
III. GUIDANCE AND CONTROL SYSTEMS						
1. Navigation and guidance						
Inertial platform	x		x			
Space sextant			x	x		
Computer			x			
Periscope assembly						x
Controls and displays	x	x	x	x		
Electronics assembly			x			
2. Stabilization and Control Sys.						
Attitude reference	x		x			
Attitude and rate displays	x		x			
Control electronics assembly			x			
Manual controls	x	x	x			
3. Orientation Control Sys.						
Thrust Vector Control Sys.						
Velocity cut-off control system	x					

Table V. (Cont.)

Items to be Monitored	Monitoring Schedule and Method of Transmission					
	During Special Phases (eg. Launch, Reentry)		Preestablished Schedule (Periodic/aperiodic)		Critical Threshold Exceeded	
	TLM	VOICE	TLM	VOICE	TLM	VOICE
III. GUIDANCE AND CONTROL SYSTEMS						
4. Propellant utilization system			x	x		
5. Service Module Propulsion system						
Propellant			x			
Oxidizer			x			
6. Command modules Reaction Control						
Propellant			x			
7. Lunar orbit retrograde System			x	x		
8. Earth landing system						
Postentry stabilization	x		x			
IV. COMMUNICATIONS						
1. Voice			x			
2. Telemetry			x			
3. Television			x			
4. Radar transponders			x			
5. Radio recovery aids			x			

Table V. (Cont.)

Items to be Monitored	Monitoring Schedule and Method of Transmission					
	During Special Phases (eg. Launch, Reentry)		Preestablished Schedule (Periodic/aperiodic)		Critical Threshold Exceeded	
	TLM	VOICE	TLM	VOICE	TLM	VOICE
IV. COMMUNICATIONS						
6. Antenna subsystem			x			
7. Radar attimeter			x			
V. LUNAR LANDING MODULE SYSTEMS						
1. Lunar impact system	x	x	x			
2. Guidance and Control Sys.	x	x	x			
3. Reaction Control Sys.	x	x	x			
4. Retrograde/landing engines	x	x	x			
VI. SPACE LABORATORY MODULE SYSTEMS						
1. Reaction Control Sys.		x	x			
2. Environmental Control Sys.		x	x			
Metalobe		x	x			
Equip. Temp. Regulation			x			
Controls		x	x			
atmospheric pressures						
humidity						
temperature						
3. Electrical Power supplies			x			

Table VI. Information Requirements For Network Coordination Functions

TABLE IV	Status							
Equipment Systems	Go/No Go	Cause	Time of Failure	Expected Down Time	Time of Acquisition	Time of Acquisition Loss	Time on Target	Critical Meteorological Factors
Radars	x	x	x	x	x	x	x	x
Telemetry	x	x	x	x				x
Acquisition Aids	x	x	x	x	x	x	x	x
Communications	x	x	x	x				x
TTY	x	x	x	x				x
Voice	x	x	x	x				x
Microwave	x	x	x	x				x
Space Communications	x	x	x	x				x
Voice Link	x	x	x	x				x
Television System	x	x	x	x				

3.5 Launch Control Center. -

3.5.1 Functions. - The launch control center functions shall include the following:

a. Monitor countdown and launch progress

b. Consult periodically with meteorological advisors

c. Advise the Mission Operations Coordinator of the MCC of mission progress and emergency situations affecting countdown and launch operators

d. Coordinate with booster contractor representatives

3.5.2 Spacecraft Systems Monitoring. - The LCC will provide monitoring and control consoles for each spacecraft system. The LCC will exercise control over the spacecraft during the prelaunch, countdown and launch phases.

3.5.3 Data Processing. - The LCC will require data which has been processed by computer complex at MCC, by computer facilities at Cape Canaveral, and by data processing equipment located in the Central Instrumentation Facility. Depending upon its location and configuration, the LCC will also require data processed by the Ground Support Equipment which is unique to the particular spacecraft under test.

3.5.4 Communications Terminal. - The LCC shall be capable of maintaining the following voice contacts:

a. Continuous contact with MCC

b. Contact with any remote GOSS station as required.

c. Contact with the spacecraft, ground operations forces, and flight crew during the pre-launch and launch phases.

d. Continuous contact with the spacecraft and flight crew during the powered phases of flight.

3.5.5 Tracking Requirements. -

3.5.5.1 Launch. - Tracking is necessary during launch to satisfy range safety requirements during boost and to obtain the vehicle trajectory data needed to verify injection into an earth orbit. During the Research and Development flights, trajectories, other than earth-orbits will be planned. These must be tracked to provide the position, velocity and impact area data necessary for mission evaluations.

Multi-radar tracking involving simultaneous beacon-track and skin-track of the spacecraft and launch vehicle major stages is required during launch. This provides redundant position and velocity information for satisfying the above mentioned requirements, and in addition, permits impact determination of the major launch stages after their separation.

3.5.5.2 Post Launch. - During subsequent overhead passes of the Apollo spacecraft at near-earth ranges the LCC shall function as a remote station as detailed in paragraph 3.5.7 below. At such times tracking support from the AMR shall be similar to that required of the GOSS remote stations.

3.5.5.3 Accuracy Requirements. - There is, at this time, no indication that the tracking accuracy requirements of the Apollo spacecraft (during the launch or post-launch conditions described above) will exceed the requirements imposed on the Atlantic Missile Range by current manned space programs.

3.5.5.4 Spacecraft Compatibility. - The spacecraft will have a C-band radar beacon system, compatible with the existing C-band instrumentation radars at AMR and throughout the MERCURY-GEMINI-GOSS network.

The reader is referred to the GOSS equipment specification, SID 62-77, for additional material on tracking equipment.

3.5.6 MCC-LCC Interface. - The primary responsibility for overall conduct of the mission lies with the MCC. The MCC will delegate responsibility to the LCC in order to accomplish the following tasks:

a. Preparation of the Spacecraft-Booster combination for launch.

b. Checkout of all Spacecraft-Booster systems.

c. Coordination with all AMR support agencies.

d. Preparation of the Flight Crew.

e. Conduct of the countdown, and adjustment of holds and zero time in conjunction with MCC.

f. Conduct of the launch to lift-off.

The LCC shall be capable, if deemed necessary and so instructed by MCC, of monitoring the Spacecraft-Booster combination trajectory and systems during the powered flight phase through injection. The trajectory displays, systems displays, and data switching capabilities shall be so designed that the LCC may perform the basic functions of the MCC in any emergency. This capability shall include that of utilizing guidance or trajectory data which is processed by local or Cape facilities.

3.5.7 LCC as a Remote Site.- The LCC, or some specific area within the LCC, shall function as a normal GOSS Remote Site during the Earth-Orbital phases of the Apollo Mission. The tracking and position data displays and spacecraft systems monitor consoles will function as those at other GOSS Remote Sites. The Cape Canaveral Remote Site will transmit position and systems information to the MCC during the periods of orbital contact.

3.5.8 Simulation and Training.- The LCC shall be capable of and will participate in training exercises of three major types.

a. Independent exercises which will involve all LCC consoles, equipment and personnel as utilized during the countdown and launch phases of Apollo missions. These exercises will include the flow of simulated data from the spacecraft, booster and support facilities; they will include the simulated loss of data sources, equipment malfunctions, system malfunctions, and normal and abnormal data.

b. Integrated exercises involving the LCC, launch complex and all Cape support agencies. These will include procedural development drills for the countdown and launch phases of Apollo Missions. These exercises will include the flow of simulated data from Cape located guidance computers exercising control over the booster.

c. Integrated exercises involving the LCC, launch complex, Cape support agencies and the MCC.

3.6 Remote Station Network. - The remote station network shall consist of the following types of stations:

a. Near-earth Remote Stations. These land or ship stations shall support the Apollo missions during earth orbit and reentry mission phases. Some stations shall be fully implemented so as to meet all

tracking coverage requirements for the foregoing mission phases, provide voice communications with the spacecraft, receive telemetering data, and provide for selecting, processing, editing and relaying spacecraft status data to the MCC. Some stations may be partially implemented, so as to either augment the basic communications coverage, or to augment the tracking coverage for specific missions or mission phases. All stations shall be provided with two way voice communications with the spacecraft.

b. DSIF or equivalent stations. These stations shall support the spacecraft mission during the trans-lunar, trans-earth, and lunar phases of Apollo missions.

c. Alternate Landing Sites. Units stationed at these sites will support the capsule during re-entry and landing, providing voice communications with the spacecraft, and providing other support for reentry and recovery operations.

3.6.1 Near Earth Remote Stations

3.6.1.1 Remote Stations Functions. - For the purpose of this section, a remote station shall be considered as consisting of a radar, a telemetry receiver, a stored program digital computer, displays relating to the flight mission and to the ground environment, and a two-way teletype data link and two-way voice link with the MCC. The detailed requirements of individual stations, whose equipment configuration departs from the above, can be adapted from those described herein. For the purpose of this paragraph, instrumentation ships may be considered as remote stations.

The functional organization of the remote station may include the following personnel:

a. Station Supervisor

b. Spacecraft Communicator

c. Maintenance Supervisor

d. Spacecraft System Monitor

e. Aeromedical Specialist

The Station Supervisor shall:

a. Supervise station operations.

b. Exercise management decisions.

c. Confer with MCC network coordinator as required or deemed necessary.

The Spacecraft Communicator shall:

a. Communicate with the spacecraft during the time the station is responsible for tracking and monitoring the spacecraft as directed by the MCC.

b. Implement MCC or other authorized station voice communication with spacecraft.

c. Implement command and control of spacecraft as directed by the MCC.

The Maintenance Supervisor shall:

a. Monitor station equipment status.

b. Coordinate maintenance and modification of station facilties.

The Aeromedical Specialist shall monitor spacecraft crew aeromedical status and performance and inform MCC of aeromedical observances. (At selected sites only.)

The Spacecraft Systems Monitors shall:

a. Monitor spacecraft systems and physical environment.

b. Evaluate and analyze malfunctions and deficiencies associated with spacecraft systems.

c. Inform the MCC of evaluated systems and provide, if possible, recommendations for corrective action.

3.6.1.2 Information Flow. - The spacecraft-earth and earth-spacecraft information densities are discussed in the following sections. A two-way information flow diagram is shown in Figure 17.

3.6.1.2.1 Spacecraft-Earth Information Densities. - Communications from spacecraft to surface stations shall be transmitted in the following modes:

a. Telemetry

b. Information Voice

c. Emergency Voice

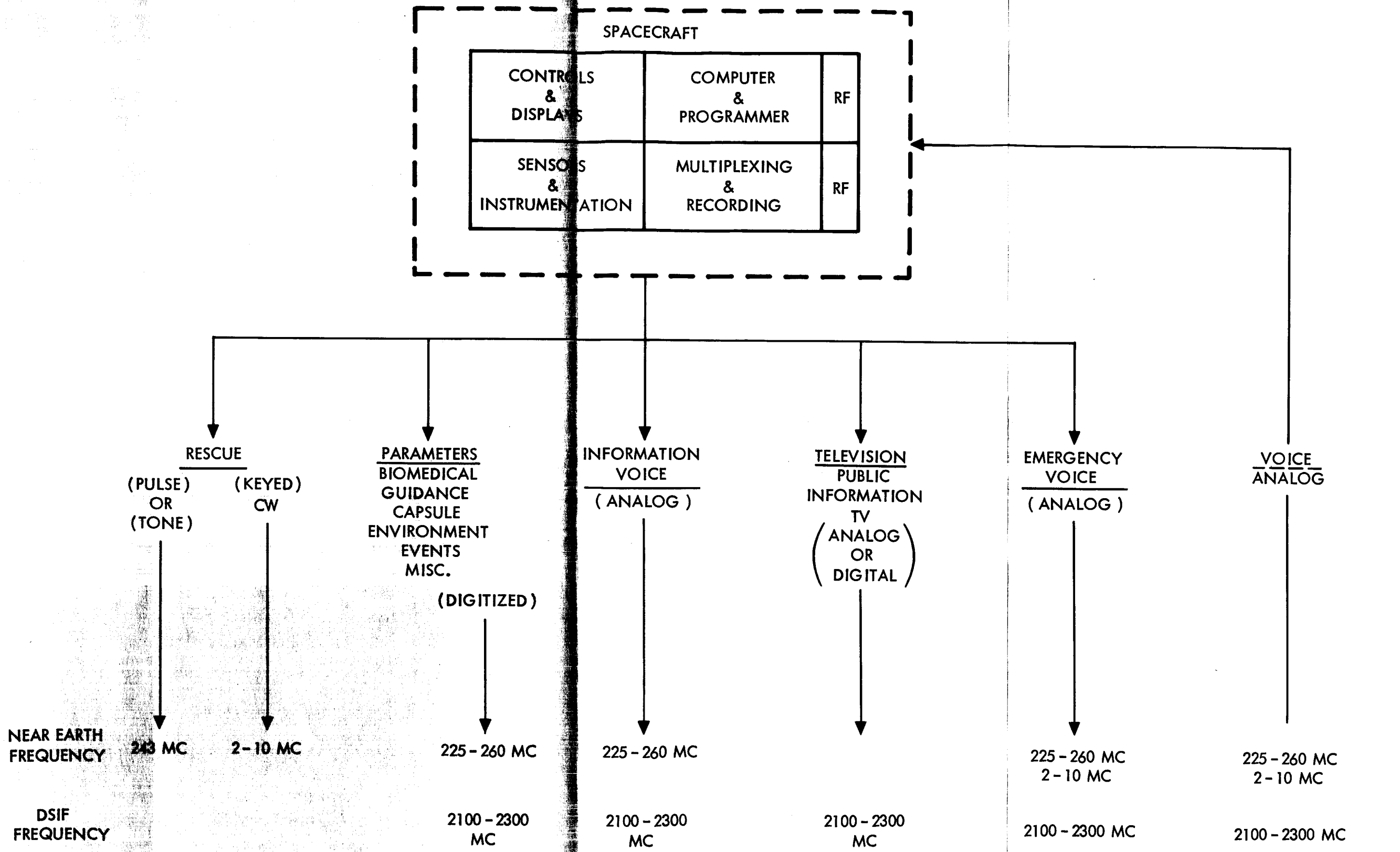

Figure 17. Information Flow to and from Spacecraft

The frequency of transmission for these modes will depend on the mission and the need for communicating with surface stations and control centers. Details of the nature, quantities, and the manner of processing information transfer between the spacecraft and the earth will be determined.

3.6.1.2.1.1 Earth Orbital Mission. - The following are types of data transfer requirements:

a. Capsule measurements of conditions affecting crew safety and critical system performance transmitted on priority basis

b. Physiological measurements of the crew

c. Navigation and guidance data transmitted as required to permit surface check of spacecraft position and course (transmitted intermittently upon crew command or by on-board programmed command)

d. In addition to real time transmission, provision for tape storage with transmission readout on decision by the crew.

e. Monitoring of long term trends on a real or near real time basis

f. For a PCM telemetry system, and estimated 64,000 bits/second of digital data consisting of the above typical information.

g. Emergency analog voice for backup to normal analog voice.

3.6.1.2.1.2 Orbital Rendezvous and Docking. - The entire orbital docking operation will require communications support between the spacecraft and earth. The spacecraft transmissions will include:

a. Capsule environment, crew status, and positive indication of missed or achieved docking.

b. Transient status before proceeding to docking position.

3.6.1.2.2 Earth-Spacecraft Information Densities. -

3.6.1.2.2.1 Earth Orbital Mission. - Communications to the spacecraft shall be by voice, and shall vary in frequency and length of transmission depending on mission phase and need for communicating from remote stations and the control centers.

3.6.1.2.2.2 Orbital Rendezvous and Docking. - Probable earth-to-spacecraft messages will be voice direction of mission adjustments.

3.6.1.3 Data Processing and Display. -

3.6.1.3.1 Processing of T/M Data. - The data processor shall be able to select telemeter data received from the spacecraft, summarize or otherwise edit the data for local printout or display, and relay the data to the MCC.

3.6.1.3.1.1 Routine Data Processing. - The station computer shall accept incoming data, perform error detection and correction operations as required, and forward the new data to the proper destination. The average value and/or limits of the telemetry data, previously received from MCC, shall be stored in the computer. The spacecraft data received via telemetry ground stations shallbe compared with previously stored parameters. If any of the measurements fall outside of the preassigned limits, the computer shall perform a verification to reject bad data points. Signals falling outside allowable limits shall be identified, and transmitted to the MCC.

3.6.1.3.1.2 Special Message Processing. - The local station computer shall modify the format and contents of the transmitted telemetry data as required by the MCC or upon recognizing specified abnormal conditions (e.g., high temperature). The modified message may represent a higher sampling rate or preselected diagnostic information to be transmitted on a priority basis.

3.6.1.3.1.3 Input-Output Buffering. - The computer may be used to compute and format the data for input-output buffering.

3.6.1.3.1.4 Data Priorities. - Telemetry data priorities are normally established by the MCC prior to performing the mission.

3.6.1.3.1.5 Temporary Storage. - The data processor shall have adequate capacity for temporarily storing overflow telemetry data in the event that peak data rates exceed the capacity of the communications circuit.

3.6.1.3.2 Processing of Radar Data. - Since most of the radar stations are equipped with a data processor, this processor can be used to good advantage to reduce requirements on the communication link bandwidth for the radar data.

The following computations and formatting can be performed on the computer:

a. Accept new target coordinates from the radar.

b. Edit radar data.

c. Perform servo-error corrections.

d. Smooth the data in the original coordinate system (for example, in polar coordinates). Minimum of three smoothed radar data points should be ensured from radar curve to define the orbit.

3.6.1.3.2.1 Computation of Designation Data. - The station computer shall be able to compute designation data for all tracking pedestals on the station.

3.6.1.3.2.2 Computation of Look Angles from Orbital Elements. - The station computer shall be capable of accepting orbital elements from the MCC and convert them to look angles and range for pointing the radar and telemetry antennas. Look angles shall be furnished to the antennas at a data rate consistent with the servo-bandwidths of these devices. The same set of updated orbital parameters can be transmitted by the MCC to each station in the GOSS network having a data processor. This will further reduce the bandwidth and time demands on the communications links. It will also increase reliability of transmission. The look angles from orbital parameters can be generated (for example, on paper tape) before acquisition of the spacecraft, thus saving computer time and storage for real time computations.

3.6.1.3.3 Input Buffer Storage. - Adequate input buffer storage capacity shall be provided for the following information:

a. GOSS timing

b. Teletype data

c. Radar tracking data

d. Telemetry data

e. Magnetic tape inputs for system simulation, system checkout, angle data from acquisition radar, telemeter data playback for retrieval, emergency landing data for recovery.

3.6.1.3.3.1 Added Requirements for Shipboard Computer. - Shipboard computers shall include buffer storage for ship position and stability information.

3.6.1.3.4 Outgoing Data. - The computer shall be able to select data for transmission, generate the required format, and schedule outgoing data transmissions.

3.6.1.3.5 Data Recording. - Data shall be recorded on magnetic tape for in-flight and post-flight analysis. The following items shall constitute a minimum requirement:

a. All incoming and outgoing messages including communications, telemetry, and designation data

b. All radar tracking data

c. Critical events and time of occurance entered by station personnel.

d. Critical decisions made within the computer.

3.6.1.3.6 Data Recovery. - Data recording and retrieval equipment shall be provided.

3.6.1.3.7 Displays. - Displays may be provided at the remote stations for monitoring the spacecraft systems, control functions, and status of station equipment, and for indicating operational modes. If practicable, the basic displays shall be easily modified for use in all programs. The displays for the individual stations will vary according to station type. Listed below are typical remote station display functions:

a. To monitor communication contact with spacecraft crew and other stations.

b. To monitor the status of the spacecraft's integrity, subsystems operation, physiological and psychological condition of the crew.

c. To monitor tracking contact with the spacecraft in order to provide continuous prediction of the vehicle position.

d. To present re-entry information.

e. To present navigational information.

f. To monitor television signals from the spacecraft.

g. To aid in monitoring scientific experimentation.

The following display types are required at a typical remote station. The displays may vary at landing stations and at DSIF stations. The latter display requirements are still being studied. (The general requirements for wall displays and consoles are described under MCC displays, section 3.4.2.1.1,

although the requirements in this section are more restrictive as they pertain only to remote station monitoring.

1. World Map Display

2. Mission Event Sequence Status Summary Display

3. Remote Station Communication Status Summary Display (local summary)

4. Weather Status Summary Display (local summary)

5. Remote Station Equipment Status Summary Display (local summary)

6. Station/ Spacecraft Communication Contact Display

B. CONSOLES

1. Spacecraft Communicator Console

2. Station Equipment Status Console and Deviation Printout. Function: monitor all systems, consoles and remote station facilities, and be able to record on a hard copy the deficiencies found during operation

3. Spacecraft System Status Console and Associated Displays (function same as MCC)

4. Environment Status Console and Associated (function same as MCC)

5. Spacecraft Crew Status Console and Associated Displays (function same as MCC)

6. Recovery Force-Recovery Area Status Console and Deviation Printout (function same as MCC)

3.6.1.4 Tracking Requirements*. - The remote stations are responsible for tracking the Apollo Spacecraft in the near-earth region. Near earth is to be construed to encompass that volume of space contained between an earth centered sphere whose surface is 400 nautical miles above sea level, and a plane which is tangent to the earth's surface at the site of the tracking radar.

*For additional information on the radar aspects of Apollo see Appendix B.

The tracking system shall monitor and evaluate spacecraft position and velocity during:

a. The Research and Development Phase

b. The Earth-Orbital Mission

c. The Pre-and-Post Rendezvous Phases of the Lunar Mission

d. The Re-entry Phase of the Earth-Orbital Trajectory and the Translunar Trajectory (return from the launch area)

e. The Translunar Phase when the spacecraft is leaving is earth orbit.

The tracking system shall provide sufficiently accurate position and velocity measurements to permit the following functions to be accomplished:

a. The establishment of the spacecraft orbital parameters by the MCC early in the first orbit and regular updating of these parameters during subsequent orbits.

b. Evaluation of mission progress by MCC.

c. Determination of the spacecraft impact point in the event of a planned or emergency landing.

d. Determination of backup position and velocity information for the spacecraft navigation and guidance system.

Accuracy requirements for ground tracking as a backup to the on-board navigation and guidance system during critical mission phases are given below. Although the data given is preliminary and does not reflect current NAA studies in this area, it is believed to be realistic.

For the sake of editorial convenience, the critical phases of lunar flights are included in the following list and will be referred to in the subsequent section concerning the DSIF. Certain critical phases will be tracked by both near-earth and DSIF stations.

3.6.1.4.1 Unmanned Earth Orbit — Near Circular. -

Injection: σ position = 0.5 n mi

σ velocity = 8 ft/sec

Later: σ altitude - 0.2 n mi

σ LHA = σ DEC = 0.01 deg.

The above values are also applicable to parking orbits. Injection values are associated with actual inertial components and the acceptable eccentricity in the nominal trajectory. The "later" values represent values to be attained with statistical smoothing of range versus time data, sensed with a precision no worse than ten times the rms errors to be expected with FPS-16 equipment. Range rate can be derived quite accurately from the orbital elements obtained from range-time data.

3.6.1.4.2 Manned Earth Orbit — Near Circular. -

Injection: Same as 3.6.1.4.1 above.

Later: σ position = 2 n mi

The above values are also applicable to parking orbits.

The additional indication of 2 n mi positional accuracy reflects the capability of on-board optical sensing to obtain position fixes.

3.6.1.4.3 Manned Earth Orbit — Elliptical. -

No data

There is as yet no data to establish the required accuracy for highly eccentric orbits.

3.6.1.4.4 Injection Into Trans-Lunar Trajectory. -

σ velocity = 9 ft/sec

σ position = 1 n mi

σ path slope = 0.02 deg.

Standard deviations of the quoted magnitudes are defined by capabilities of present digital inertial guidance and the limitation of required midcourse correction to 100 ft/sec or less rms. Any existing range tracking installation, if in view of this injection point, would exceed these accuracy requirements.

3.6.1.4.5 Midcourse Corrective Maneuver. -

σ velocity = 0.1 ft/sec

Midcourse maneuver velocity accuracy limitation is one which limits lunar arrival uncertainties to approximately 2 miles. Only DSIF or equivalent equipment is known to have the required range. Its rms errors of 0.02°, 0.7 ft/sec and 0.25 miles, when associated with suitable and existing orbit determination procedures, are suited to this requirement. About four hours of tracking time would be needed.

3.6.1.4.6 Near-Circular Lunar Orbit. -

Entry conditions: σ position = 2 n mi

σ velocity = 2 ft/sec

After sensing and data processing: σ altitude - 0.1 n mi

σ range = 1.3 n mi

σ altitude rate - 0.4 ft/sec

σ velocity = 0.7 ft/sec

Entry conditions are determined by the requirement to fix a circum-lunar orbit suited to pre-landing reconnaissance. The tracking accuracies of 3.6.1.4.4 are capable of exceeding this requirement. The values quoted as "after sensing and data processing" are results of digital computer study of an orbit determination program using 1% accuracy radar altimeter lunar altitude sensings.

3.6.1.4.7 Letdown From Near-Circular Lunar Orbit to Final Approach Altitude. -

σ altitude = 0.1 n mi

σ velocity = 0.7 ft/sec

σ altitude rate = 0.4 ft/sec

σ range = 1.3 n mi

No radio tracking technique is seen to be suitable here.

3.6.1.4.8 Lunar Landing. -

σ position = 5 n mi

σ velocity = 5 ft/sec horizontally

= 10 ft/sec vertically

No radio tracking technique is seen to be suitable here.

3.6.1.4.9 Lunar Pre-Takeoff Cockpit Check. -

σ azimuth = 20 sec of arc

σ position = 0.3 n mi

No radio tracking technique is seen to be suitable here.

3.6.1.4.10 Boost From Lunar Surface Into Lunar Orbit. -

σ position = 0.25 n mi

σ velocity = 1.5 ft/sec

No radio tracking technique is seen to be suitable here.

3.6.1.4.11 Injection From Lunar Near-Circular Orbit Into Earth Return Trajectory. -

σ velocity = 2 ft/sec

σ altitude = 0.1 n mi

This accuracy may be evaluated by processed DSIF sensings.

3.6.1.4.12 Approach to Earth Re-Entry. -

σ altitude = 4,000 ft

σ position = 10 n mi

σ path angle = 0.1 deg.

σ velocity = 15 ft/sec

These accuracies assume tracking errors (rms) of approximately one mile for range, and 10 ft/sec. for range rate, for the region from 40,000 miles altitude to re-entry.

The spacecraft is assumed to have a high altitude radar altimeter providing maximum errors of 2 percent.

3.6.1.4.13 Earth Re-Entry and Landing. -

σ position = 10 n mi

σ velocity = 10 ft/sec

1-σ range uncertainty of ground radio tracking should not exceed 1/4 mile. The 30 n mi figure above refers to spacecraft touchdown dispersion.

Mercury tracking accuracy assumed to be adequate.

3.6.1.4.14 Re-Entry Test and Development Flights, Including Power-On Re-Entry. -

σ velocity = 5 ft/sec

σ position = 6 n mi

Mercury tracking accuracy assumed to be adequate.

3.6.1.4.15 Emergency Mission Termination and Return. -

Accuracy is dependent on the mission phase and location of spacecraft.

3.6.1.4.16 Earth Orbital Rendezvous. -

σ position (relative to target) at 40 n mi range = 4 n mi

σ velocity = 5 ft/sec (relative)

σ path angle = 0.2 deg.

Rendezvous in earth orbit requires the tracking accuracies of 3.6.1.4.1, supplemented by on-board radar of 1% accuracy and 150 n mi range. A radar beacon is assumed aboard the tanker.

3.6.1.4.17 Moon Orbital Rendezvous. -

Earth based radio tracking techniques are believed to be unsuitable here.

3.6.1.5 Spacecraft-Ground & Ground-Spacecraft Communications. - Communications between the Apollo spacecraft and the MCC shall be transmitted via the GOSS network remote stations which have line of sight contact with the spacecraft.

3.6.1.5.1 Research and Development (R&D) Missions (Boilerplates, 13, 15, 16 & 18 and AFRM's 007 & 010.). - Previous to operational missions, there shall be 6 R&D unmanned missions. Missions B-13, B-15, B-16 & B-17 shall be earth orbital and non-recoverable. Missions AFRM 007 & 010 shall be ballistic and recoverable. For each of these missions the information transfer from and to the spacecraft shall vary.

The GOSS requirements for these missions shall be specified in the following paragraphs. The 4 PAM/FM/FM telemetry transmitters indicated shall require a GOSS capability for IRIG band 2-16 and channel E. Ground-spacecraft up-data transmission shall be required corresponding to the R. F. links indicated.

In establishing communications requirements for the GOSS system the following modes are currently recognized.

3.6.1.5.1.1 Earth Orbital - Non-Recoverable (B-13, B-15, B-16, & B-18).-

a. T/M, 225-260 mc, PAM/FM/FM 4RF links (R&D)

b. Command, 406-450 mc, FM, coded, IRF link (R&D)

c. Tracking, 5400-5600 mc 2 Transponders (R&D)

d. DSIF Checkout, 2100-2300 mc 1 Transponder (Oper.)

3.6.1.5.1.2 Ballistic Trajectory-Recoverable (AFRM 007 & AFRM 010).-

a. T/M, 225-260 MC, PAM/FM/FM 4 RF links (R&D)

b. T/M, 225-260 MC, PCM/FM IRF links (Oper.)

c. Command, 406-450 MC, FM, coded, IF link (R&D)

d. Tracking, 5400-5600 MC 2 Transponders (R&D)

e. DSIF Checkout, 2100-2300 MC, 1 Transponder (Oper.)

3.6.1.5.2 Operational Missions. - Earth orbital spacecraft operating in the vicinity of the earth and not exceeding 400 n.m. altitude will communicate

to the MCC via the GOSS network remote stations. The GOSS network for earth orbital missions consists essentially of a modified Mercury network. Acquisition is accomplished at present Mercury stations by the telemetry signal. Where the stations presently assist in directing the radars onto the spacecraft, it will be desirable to preserve this capability of acquisition aid for Apollo near-earth orbits. There is no requirement at present for an up-data link.

In establishing communications requirements the following modes are currently recognized.

3.6.1.5.2.1 Spacecraft-to-Earth Modes. -

3.6.1.5.2.1.1 Normal Telemetry. -

a. 225-260 MC

b. PCM/FM

c. PCM/FM capability will be required at the surface stations. This type of modulation is currently planned for Minuteman, Polaris, and Gemini. If it is installed for these programs it will be available for earth orbital Apollo missions.

3.6.1.5.2.1.2 Normal Voice. -

a. 225-260 MC

b. AM

c. Adequate system margin is available. Capability exists at present in Mercury range.

3.6.1.5.2.1.3 Backup Voice. -

a. 225-260 MC

b. AM

c. Adequate system margin is available. Capability exists at present in Mercury net.

3.6.1.5.2.1.4 Normal Tracking, Ranging. -

a. 5400-5600 MC

b. Pulse

c. Capability exists at present in the Mercury network. System margin is marginal.

3.6.1.5.2.1.5 DSIF Checkout - T/M, TV, Voice, Tracking. -

a. 2100-2300 MC

b. Various modulation techniques

c. Adequate system margin is available at present in all modes.

3.6.1.5.2.2 Earth-To-Spacecraft Modes. -

3.6.1.5.2.2.1 Normal Voice. -

a. 225-300 MC

b. AM

c. Adequate system margin is available. Capability exists at present in most Mercury network stations. It is planned to have voice capability at all Apollo-GOSS remote stations.

3.6.1.5.2.2.2 Normal Tracking, Ranging. -

a. 5400-5600 MC

b. Pulse

c. System margin is marginal. Capability exists at present in Mercury network.

3.6.1.5.2.2.3 DSIF Checkout Voice. -

a. 2100-2300 MC

b. FM/PM

c. Adequate system margin is available.

3.6.1.6 Communication Terminal. -

a. Means shall be provided at the communications terminal to permit selected data to be transmitted on a real time basis, and other data to be transmitted on a delay basis in accordance with its delivery (priority) requirements.

b. Determination of the use of overall error-control shall be made on an individual circuit basis. Where error control is employed means shall be provided at the communications terminal to detect errors in data transmission. It shall be possible, at the discretion and under control of the communications terminal operator, to cancel error control when required.

3.6.1.7 Remote Station System Operability Verification, Exercise, and Checkout Requirements. - The remote station shall have simulation equipment for performing the following tasks:

a. Verification of unit, equipment, and station operability.

b. Station exercise, using simulated spacecraft and MCC inputs.

c. Station checkout.

d. Personnel training.

e. Station procedures development.

The equipment shall be adaptable to variations in the remote station and GOSS network configuration, and to changes in operating procedures and mission goals; and shall be expandable to accommodate additional station equipments and functions. Existing simulation, checkout, and test equipment shall be utilized whenever practicable.

3.6.1.7.1 Remote Station Operability Verification Requirements. - Simulation equipment capable of rapidly determining the overall operability of each equipment system at the station and of the station as an integrated whole shall be provided at each remote station. Simulated radar, telemetry, communications and command signals may be used, and the output compared with predetermined required values. The results of the verification tests shall be displayed at the station and shall be transmitted in summary form to the MCC.

3.6.1.7.2 Remote Station Exercise Requirements. - Each remote station shall be provided with equipment having the capability to exercise equipment and personnel independently. The equipment shall be capable of simulating the Apollo spacecraft data anticipated during any of the planned Apollo missions and flight profiles. Provision shall be made for exercises deviating in various degrees from planned missions and mission profiles. The equipment shall also provide for simulation of the interface with the MCC and for simulation of interfaces with other remote stations where they exist. Provision shall be made for the introduction of noise into communications channels, for controlled degradation of signals, and for the simulation of malfunctions. The exercise equipment shall be designed to be flexible and adaptable. The basic design objectives of the exercise equipment shall be to provide a means for developing procedures and techniques for training personnel, and for achieving and maintaining a high degree of personnel proficiency.

3.6.1.7.3 Remote Station Checkout Requirements. - The GOSS simulation of the remote station shall be designed to serve as an aid to maintenance. The basic objective shall be to rapidly determine the location of any existing equipment malfunctions. Each remote station shall be provided with simulating equipment capable of rapidly and selectively checking the station equipment to determine whether operation is within specifications, marginal, or beyond allowable tolerances. The tests shall be made by introducing controlled synthetic signals and data into the station equipments and, at selected points, comparing equipment outputs with predetermined values. These tests and comparisons preferably shall be performed semiautomatically. The tests shall include the radar equipment, telemetry equipment, data processing equipment, displays, and communications equipment. Tests of the radar equipment and telemetry equipment shall include determination of antenna pedestal and servo operability. Checkout of the communications equipment shall include tests of the station-to-spacecraft and the station-to-MCC communications equipments. Tests of digital data links and data processing equipment shall be included.

The results of the checkout tests shall be displayed and reduced to hard copy at the station and shall be transmitted to the MCC when required.

3.6.1.7.4 Remote Station Simulation Requirements. - The simulation equipment associated with the GOSS remote stations shall support the requirements for operability verification, exercise, and checkout. This section covers the general nature of the signals which shall be simulated.

The remote station simulation equipment (Figure 18) shall provide for the simulation of the spacecraft station and MCC station interfaces.

a. Radar Signal Simulation. - The remote station simulation equipment shall provide for the simulation of radar echoes from the spacecraft. The simulation shall provide means for checking the ability of the radar system to track the spacecraft and shall provide for the introduction of noise and for the control of the echo signal-to-noise ratio.

b. Telemetry Signal Simulation. - The remote station simulation equipment shall provide for the simulation of telemetry data from the spacecraft. (The simulation shall include means for determining the ability of the telemetry equipment to track the spacecraft.) Means shall be provided for introducing noise and for control of the signal-to-noise ratio. Means shall be provided to allow unrestricted choice of the information content of the simulated telemetry data.

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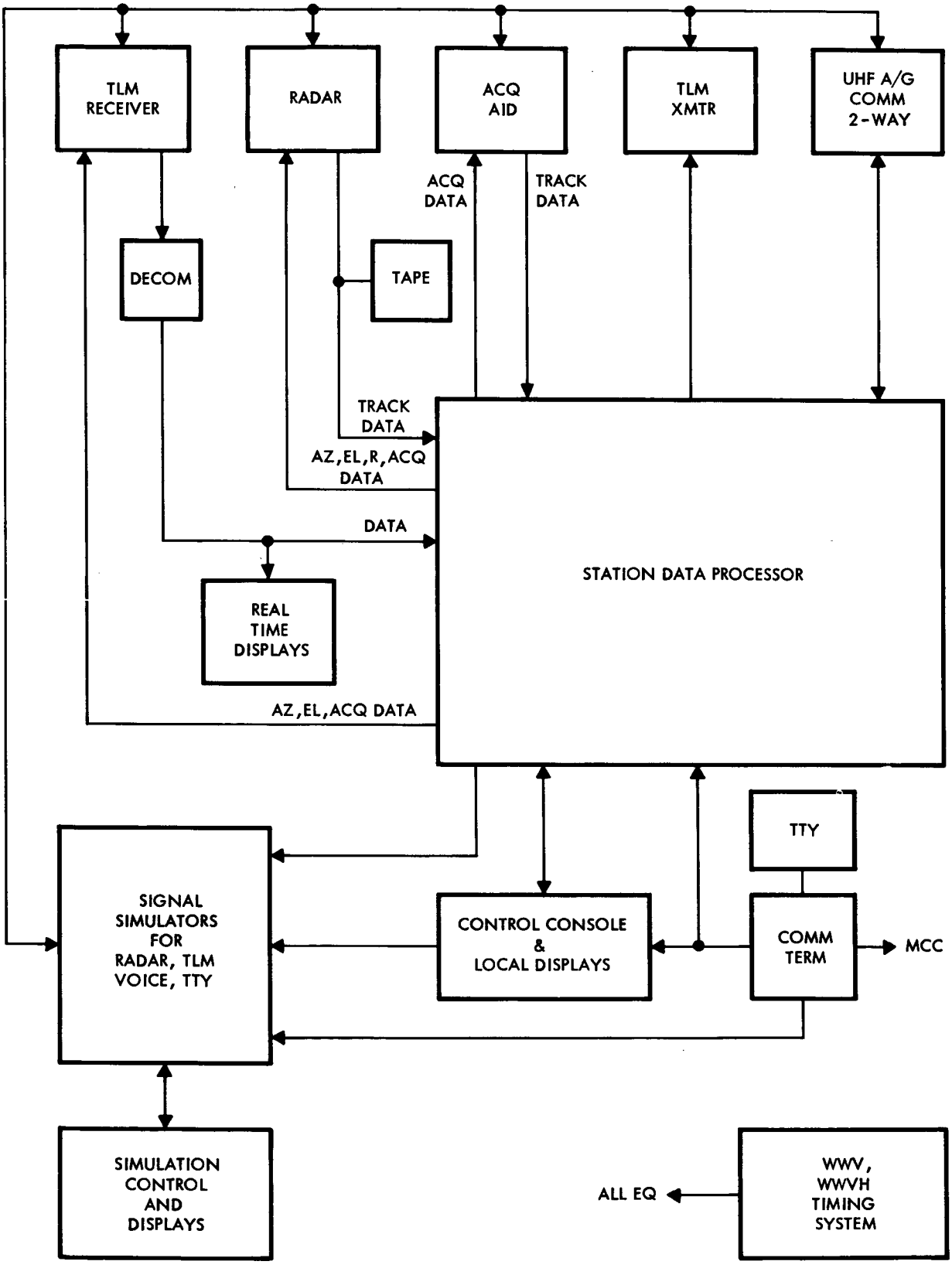

Figure 18. Remote Station Simulation System

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c. Communications Simulation. - The remote station shall be provided with means for simulating voice communications, digital data, and teletype transmissions similar to the means of the MCC.

3.6.1.7.5 Operational Verification Requirements During Actual Mission. - During an actual mission, means shall be provided to exclude any undesirable interference of the simulated data with any circuit or equipment. However, it shall be possible to perform operability verification tests during actual mission at the specific direction of the mission operations director. The simulation equipment shall be designed to monitor the remote station equipment during actual mission without interfering with GOSS operational requirements.

3.6.1.7.6 Demonstration and Acceptance Test Simulation Requirements. - The remote station verification, exercise, and checkout equipments shall be designed and implemented for performing acceptance tests and operational capability demonstrations for individual equipments, stations, the MCC, and the GOSS network.

3.6.2 Remote Landing Sites. - For recovery operations the Apollo landings will be classified as scheduled and unscheduled landings. Scheduled landings are those landings where the spacecraft can reach a designated primary, alternate or emergency landing site. Scheduled landings include emergency landings where retro time can be selected to get into one of the above classes of landing sites. Unscheduled landings are those landings resulting from emergencies that prevent the spacecraft choosing the retro position and reaching a designated landing site.

3.6.2.1 Recovery Requirements. - The general requirements for recovery are the following:

1. Airborne, Land and Ship VHF and HF Communications
2. Airborne VHF Direction Finder
3. Land and Ship based VHF Direction Finder
4. Land and Ship based HF Direction Finder
5. Land and Ship based Helicopters

For scheduled landing establishing communications with the spacecraft after re-entry should not difficult. The communications horizon at drogue chute deployment is of the order of 400 miles and at main chute deployment it is approximately 200 miles. During landing descent it will be possible to

obtain bearings on the communication transmissions and the VHF beacon. In addition, the landing sites will obtain range and azimuth data from radar tracking of the spacecraft during re-entry and landing descent.

The operational procedure will be to establish contact with the spacecraft after re-entry and determine crew and craft status. Land based, ship or helicopter VHF and HF equipment will be used in maintaining spacecraft contact.

Line-of-sight communications between the spacecraft and the landing site may be terminated as the spacecraft descends below the landing site horizon; however, the helicopters assigned to each landing site should be able to supplement this link and maintain contact if the landing sequence goes according to plan. In the event this is not possible due to range requirements, the HF channel will be used to attempt to establish over the horizon contact.

The method of recovery of the crew and spacecraft will vary depending on whether the landing takes place on land or water. In either case helicopters will be used to recover the crew. Each land-based recovery site will have helicopters capable of recovering the crew and spacecraft. Land recovery may consist of the following operations. The crew will be picked up by helicopter and replaced by a spacecraft guard and recovery team. This or another helicopter will then be brought in to recover the spacecraft. This method of spacecraft recovery will eliminate the necessity of temporary road construction in the event the landing is not within the boundaries of a specified landing site and will avoid the problems of road transportation such as traffic difficulties or accidents.

For water landings that are not within a few miles of the GOSS landing site ship, a ship-based helicopter will be used for crew recovery. The helicopter will also transport a recovery crew and flotation gear if required. This method provides for short time crew aid and recovery, the helicopter also extends the communications range and permits more rapid surveillance and search of larger areas. Ship recovery of the spacecraft is selected for several reasons: A smaller helicopter can be used aboard ship and the spacecraft will normally remain afloat long enough for the ship to arrive at the landing point. Also the range limitations of most helicopters, with large loads, would require that the ship recover the helicopter and spacecraft in any case.

3.6.2.2 Functions of the Landing Sites. - The primary functions of the landing sites will be:

a. Establish contact with the spacecraft crew as early as possible.

b. Determine condition of the crew and the spacecraft.

c. Recover the spacecraft crew, place guard and preserve the spacecraft for its future recovery in case of crew recovery by helicopter or aircraft.

d. Conduct preliminary debriefing of the spacecraft crew.

e. Provide medical care for the spacecraft crew.

f. Deliver the spacecraft and the crew to the designated area.

The optional functions of the landing sites will be:

a. At those landing sites which are remote from other GOSS stations, the capability for voice communication with the spacecraft should be provided.

b. The Kermadec Islands and Easter Island landing sites should have radar capability to allow them to support landings at the Easter Island and South Atlantic landing sites, respectively, by tracking the spacecraft during its de-orbit coast phase.

3.6.2.3 Information Flow. - Communications between the spacecraft and the GOSS landing site will be accomplished by VHF and HF radio. HF radio will be used to establish contact beyond the horizon. The crew and spacecraft status will be determined by voice through VHF and HF radio and through telemetry channels. HF and VHF direction finders, radar, and telemetry trackers will supplement each other in establishing the position of the spacecraft both before and after touchdown.

3.6.2.4 Recovery Communications. - The recovery operation will require communications support between the spacecraft and earth and between the spacecraft and rescue aircraft. The spacecraft-to-earth or to-aircraft transmissions will include:

a. A signal to provide direction finding information to aircraft, ships, or land-based stations.

b. Voice transmissions to aircraft, ships, or land-based stations.

These transmissions shall be made on standard distress frequencies.

3.6.2.4.1 VHF/DF Beacon - Normal.

a. Pulse - 3W peak

b. 243 MC

c. Adequate system margin is available. Capability exists at present in the Mercury range.

d. This pulse beacon has a longer pulse width than the beacon previously proposed in order to make it compatible with receiving equipment normally installed in a greater number of rescue aircraft. The selected power level will provide 100 n. m. line of sight transmission.

3.6.2.4.2 VHF/DF Beacon - Backup.

a. Tone modulated CW - 5W average

b. 243 MC

c. Adequate system margin is available.

d. This mode is compatible with the rescue aircraft receiving equipment normally available. The selected power level will provide 120 n. m. line of sight transmission.

3.6.2.4.3 HF/DF Beacon.

a. Keyed CW - 5W peak

b. 8.364 or 2.182 MC (day or night frequencies respectively)

c. Adequate system margin is available. A beacon with the selected power level will be capable of communication ranges in excess of 1000 miles.

d. The HF beacon will be monitored by DF stations of the FCC, Coast Guard, FAA, Navy, and others.

3.6.2.4.4 VHF Voice.-

a. AM transceiver - 5W average

b. 243 MC or 300 MC. The 300 MC receiving channel will be used during recovery while the 243 MC pulse beacon is operating.

c. Adequate system margin is available. Capability exists at present in the Mercury range.

3.6.2.4.5 HF Voice.-

a. SSB transceiver - 10 W PEP

b. 8.364 or 2.182 MC (day or night frequencies respectively)

c. Adequate system margin is available. Will be used for beyond line of sight communications.

3.6.2.5 Re-entry Tracking.- The requirements for re-entry tracking are intimately related to the re-entry blackout study currently in progress at S&ID. It is anticipated that this study will provide details on the transparency or reflectivity of the plasma sheath as a function of frequency, spacecraft velocity, altitude, etc.

Subject to the study findings, the C-band radars at the primary and secondary landing sites can operate in either beacon or skintrack mode, with the radar operator switching between the two as necessary to provide the best tracking.

Tracking at the alternate landing sites during re-entry is not so well defined. The recovery force at each site will probably consist of a group of DOD vessels strategically deployed to provide efficient coverage of the area. Tracking during this period will be by skin-tracking with available radars aided by look-angle information from the GOSS network. The landing sites are located such that GOSS remote stations will provide some radar tracking of the spacecraft after the retro firing is completed. This tracking information coupled with MCC computed trajectory information shall provide valuable assistance to the recovery group in tracking during re-entry.

The accuracy requirements for re-entry tracking are not critical. The prime requirement is to maintain tracking through re-entry if at all possible so that valuable tracking time is not lost in re-acquiring radar contact after the blackout period is over. The spacecraft touchdown point can thus be

more confidently established to permit dispatching recovery craft to the touchdown area.

3.6.2.6 Unscheduled Landing Recovery.- Unscheduled and unobserved re-entry and landings present problems that will require establishing standard operating procedures and may require the assistance of the military in recovery. It is not practical to provide recovery units for all possible landing sites. However, the Navy and Air Force maintain forces throughout the world that can and do support emergency rescue operations. An operation plan should be worked out with these units for emergency recovery support.

Although the re-entry and landing of the spacecraft may occur out of range of any GOSS station, the MCC will be able to predict the possible landing areas from past tracking data and the failure of the spacecraft to enter the GOSS coverage on schedule. On the basis of this information and knowledge of the spacecraft re-entry trajectory, the MCC will be able to direct the beginning of search operations.

After an unscheduled retro the spacecraft HF and VHF communication channels should be utilized to transmit periodically the retro time and an estimate of the landing position. These transmissions, in addition to VHF beacon activation should continue until communications contact is established. The transmissions will be made on specified frequencies that GOSS stations, recovery forces, and rescue units can monitor and use for direction finding and establishing two-way communications. This procedure will facilitate the determination of crew status and spacecraft location and condition. Aircraft or helicopters participating in a search may be able to receive line-of-sight VHF transmissions at ranges of 100-250 miles. HF transmissions may be received by the GOSS at various over the horizon ranges depending on the frequency used, time of day, time of year, ionospheric conditions, etc. In addition to HF voice transmissions keying of the transmitter may be useful. For instance, if more than one GOSS station, communication site or military station obtains a bearing on the spacecraft radiation, triangulation can be used to further define the landing position. Although long-range HF direction finding presents some problems in accuracy, this system should be used in an attempt to locate the spacecraft and to establish long-range communications until recovery or rescue units can establish VHF contact.

To provide the GOSS with the capability of recovery of unscheduled landings would be an expensive effort that would duplicate some of the services and forces maintained by the military. Considering the survival capability of the spacecraft, it is recommended that the GOSS recovery units for scheduled landings and the military forces be used to effect recovery of unscheduled landings. The position of landing would determine the units to be used in recovery.

3.6.3 DSIF

3.6.3.1 Functions. - The capabilities of the Deep Space Instrumentation Facility (DSIF) for spacecraft tracking and communications at cislunar* distances and beyond are presumed to be known to the reader**.

The functions of the DSIF in Project Apollo are to provide communications, tracking, and support of the spacecraft when it is above 400 n.mi. altitude. Below this altitude the near-earth tracking system will provide the required coverage although both systems may track simultaneously where station locations are favorable for such action.

A possible requirement exists for perhaps two transportable deep space stations to provide the required tracking coverage during translunar injection and transearth re-entry of the spacecraft. This requirement is based on a preliminary investigation of the coverage provided by the three DSIF stations (Goldstone, Calif., Woomera, Australia, and Johannesburg, South Africa), the flight profiles of the spacecraft for the missions phases indicated, and the geographic area wherein injection and re-entry may occur. These stations should preferably be ship stations to permit relatively fast relocation of stations in the event of changes in the launch date. Further investigation will decide more certainly the validity of this requirement for transportable deep space stations.

3.6.3.2 Information Flow. - The transfer of information in the DSIF network is accomplished via a well-established teletype and communications network. Proposed expansion of these capabilities for Project Apollo should satisfy the increased data flow, particularly if on-site data processors are used as is recommended for the near earth stations. The information from the DSIF network shall be routed through the DSIF control and communication center at JPL for relay to the MCC. Television signals received at Goldstone will be transferred via a DSIF microwave link to the JPL center and then relayed to MCC via commercial networks. The JPL central computer shall function as a back up to the MCC computer complex.

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*Cislunar space is construed as encompassing that portion of space which the spacecraft must traverse in a translunar or transearth trajectory, including lunar orbits. Therefore, for a given station it is the volume of space defined by the planes bounding the moon's apparent orbital paths and a plane tangent to the earth's surface at the site of the station.

**A good reference for those not familiar with DSIF capabilities is, "Estimated 1963-1970 Capability of the Deep Space Instrumentation Facility for Project Apollo," Jet Propulsion Laboratory EPD-29, revised 2-7-62.

3.6.3.3 Lunar Mission Communications. - Communication coverage with the Apollo spacecraft during the translunar, circumlunar, lunar landing, and/or transearth portions of a lunar mission will be provided by the three DSIF stations. Communications coverage for the launch, parking orbit, and lunar trajectory injection portions of the lunar mission will be provided by that portion of the Apollo - GOSS remote station network that would be utilized for the near earth orbital missions. It may be necessary, however, to augment the remote station network, as previously mentioned, with transportable stations with extended communication range capability in order to have adequate communication coverage shortly after the completion of injection into the translunar trajectory.

In establishing communications requirements for the GOSS system, the following modes are currently recognized. A study is in progress to determine whether analog or digital television will be used.

3.6.3.3.1 Spacecraft-to-Earth. -

3.6.3.3.1.1 T/M, Voice. -

a. 2100 - 2300 MC

b. T/M - PCM/PM

c. Voice FM/PM

d. A 64 KBPS digital bit rate will be used.

3.6.3.3.1.2 Narrow-Band T/M. -

a. 2100 - 2300 MC

b. PCM/PM

c. Keep-alive mode used in event of primary T/M failure. A 2KBPS digital bit rate is contemplated at present.

3.6.3.3.1.3 Ranging. -

a. 2100 - 2300 MC

b. PRN/PM

c. Pseudo-random noise ranging technique is used.

3.6.3.3.1.4 Voice, Tape Playback. -

a. 2100 - 2300 MC

b. Tape Playback FM/FM

c. FM

d. Playback/record ratio of 1, possibly 3, is contemplated.

3.6.3.3.1.5 TV (Analog), TM, Voice. -

a. 2100 - 2300 MC

b. TV-FM

c. TM-PCM/PM/FM

d. Voice-PAM/FM - Occurs between the TV lines.

3.6.3.3.1.6 TV (Digital), TM, Voice. -

a. 2100 - 2300 MC

b. TV and TM - PCM/PM

c. Voice - FM

3.6.3.3.1.7 Backup Voice and Key. -

a. 2100 - 2300 MC

b. Voice-FM

c. Key-PSK

3.6.3.3.2 Earth-to-Spacecraft. -

3.6.3.3.2.1 Ranging. -

a. 2100 - 2300 MC

b. PRN/PM

c. Pseudo-random noise ranging technique is used.

3.6.3.3.2.2 Voice. -

a. 2100 - 2300 MC

b. FM/PM

3.6.3.3.3 System Circuit Margins. - Adequate circuit margins for all lunar communications links are available using the 85-foot DSIF antennas and high-gain spacecraft antennas. A degradation of the S/N will occur if it is necessary to use a smaller ground antenna or omni-directional spacecraft antenna. It is necessary, however, to use the 85-foot ground antenna and a high-gain spacecraft antenna for the television mode.

3.6.3.4 Simulation and Training. - Simulation and training in the DSIF shall follow, generally, the requirements specified for the remote stations with modifications as necessary for the differences in equipment.

3.6.3.5 Tracking. - The tracking and accuracy requirements for the DSIF stations are, for editorial convenience, included with tracking requirements listed for the remote stations. (See Section 3.6.1.4.)

3.7 Network Interfaces.- This section identifies the major interfaces of the GOSS with other elements of the Apollo project and with concurrent space programs. As the development of the GOSS progresses and additional important interfaces are identified and explicit requirements developed they will be included herein.

3.7.1 Operational Interfaces.- In operation during Apollo missions, the GOSS has major interfaces with the following:

a. The spacecraft
b. The launch vehicle
c. Apollo GSE
d. AMR equipment
e. PMR equipment
f. White Sands Range equipment
g. The DSIF stations
h. The recovery forces
i. Support functions, such as weather and solar activity forecasting
j. Overall administrative and operational control.

3.7.2 Planning Interfaces.- During the planning of Apollo missions, the GOSS has interfaces with other space programs which have requirements for the national ranges and the Mercury-Gemini-Apollo network. These are essentially as follows:

a. Mercury
b. Gemini
c. Ranger
d. Surveyor
e. Military and scientific satellite and space probe programs
f. Other government agencies and industry.

3.7.3 Development Program Interfaces.- The GOSS performance requirements will vary with the progression of the Apollo project through its planned program. Therefore, the GOSS implementation schedule (to be

established) will accommodate the Apollo program in a step-by-step process. In this process interfaces will exist between the Apollo GOSS performance requirements and the network requirements of the Mercury and Gemini projects.

3.7.4 Spacecraft. - The GOSS and the spacecraft (in all its combinations of modules for different missions) shall be mutually compatible with regard to:

a. Radar tracking

b. Telemetry, down (spacecraft to earth)

c. Television, down

d. Voice communications, up and down

This compatibility requirement must hold for near-earth and lunar distances.

The GOSS and spacecraft shall be mutually compatible with regard to providing each other with necessary information.

a. The GOSS must provide all necessary information to the spacecraft upon request as back-up to the on-board systems of the spacecraft.

b. The spacecraft must provide to the GOSS the necessary information for evaluation of the spacecraft systems status and the spacecraft crew status to permit determination of the mission progress and the adequacy of the on-board information as a basis for the crew's decisions.

3.7.5 Launch Vehicle. - The launch control center of the GOSS and the launch vehicle must be mutually compatible with the telemetry and radar systems for providing the GOSS with data on the launch vehicle performance in flight. This data must be compatible with the requirement for the GOSS to determine at all points during the boost phase the following conditions:

a. Whether or not abort would be necessary if the thrust were terminated at that instant

b. The mission capability if the thrust were terminated at that time

c. The prediction of time and point of impact in case of abort

d. The performance of the booster's systems as they affect the mission capability

e. The performance of the booster's systems as they affect the ability of the booster to complete its function without jeopardizing the spacecraft and its crew

3.7.6 Ground Support Equipment. - The LCC of the GOSS and the Apollo ground support equipment employed during the prelaunch and countdown activities must be mutually compatible. Data for spacecraft and launch vehicle systems status must be supplied to LCC through GSE, resulting in electrical umbilical interfaces and other electronic and electrical compatibility requirements.

4.0 QUALITY ASSURANCE

4.1 Reliability and Maintainability

4.1.1 System Requirement. - The GOSS system shall be designed so that the probability of the GOSS performing its specified functions shall be no less than 0.999 and further, the total downtime of any given station shall be limited to one hour in a thousand of which no one incident shall exceed 4 minutes duration at the 0.96 confidence level.

4.2 Reliability and Maintainability Program Requirements. - A reliability and maintainability program shall be established to conform to the objectives of MIL-R-27542 as amended and MIL-M-26512B respectively. A definitive program plan shall be evolved for NASA by the GOSS contractor within 30 days after contract compliance with these specifications.

4.3 Station and Equipment Requirements. - The station availabilities and maintenance time constraints shall be in accordance with the allocations given in Table C-I, C-II, and C-III of this specification and/or be such as to meet the overall system requirement herein stated. Specific equipment reliabilities shall be determined by futher allocation. Where seeming conflicts exist the system reliability requirement shall prevail, i.e., when configuration changes are anticipated. See Appendix C for mathematical model and apportionment process.

4.4 Applicable Definitions. - The following definitions shall prevail for purposes of this specification.

4.4.1 Allocated Equipment Reliability. - The probability that an equipment will operate over a specified period of time with no failure which would cause the system to operate outside of the specified limits, for more than the allowed maintenance time constraint.

4.4.2 Equipment Maintainability (Maintenance Time Constraint). - The probability that, having failed, an equipment can be restored within the specified time period. This excludes logistic considerations such as manpower, spares, etc. which must be made compatible with basic requirements to a reasonable risk level, i.e., no less than .90.

4.4.3 Availability. - Availability is herein defined as the ratio of system, station or equipment uptime to total elapsed time exclusive of logistic time considerations, i.e., supply manpower, etc.

4.4.4 Limiting Phases.- Limiting phases, as selected from Appendix C, Table C-III are distinguished by station types, i.e., earth orbital or deep space, and mission criticality. Selected limiting phases are for reference use only to demonstrate reliability criteria. See Table VII.

4.4.5 Allowable Down Time.- Allowable down time per hour is defined as the availability subtracted from unity. The allowable down time is expressed as allowable down time/100,000 hours. See Tables VII and VIII.

4.5 Demonstration Requirements.- The 0.90 confidence level shall apply to both analytical and physical demonstrations unless specified otherwise by supplemental agreement.

4.6 Total Operating Life (Longevity).- The GOSS complex shall have a minimum total operating life of 10,000 hours with reasonable servicing and replacement of parts or systems. Parts or systems requiring replacement within this interval and the life of such parts or systems shall be specified.

5.0 PREPARATION FOR DELIVERY (Not applicable)

6.0 NOTES (Not applicable)

TABLE VII

LIMITING PHASES

ALLOWABLE DOWNTIME IN HOURS/100,000 HOURS

Mission Phase Station	Earth Orbit #1	Transearth
A. Cape Canaveral	.78	
B. Bermuda	.31	
C. Grand Canary	.31	
D. Kano	.78	
E. Johannesburg (DSIF)		1.09
F. Zanzibar	.78	
G. Indian Ocean Ship	.47	
H. Muchea	.47	
I. Woomera (Remote)	.31	
J. Woomera (DSIF)		1.09
L. Canton Island	.31	
M. Kermadec Island	.78	
V. Goldstone (DSIF)		.47
W. Houston (MCC)	.78	.78
TOTAL	6.08	3.43

TABLE VIII

STATION RATINGS

ALLOWABLE DOWNTIME IN HOURS/100,000 HOURS

Station	Station Rating
A. Cape Canaveral	5.49
B. Bermuda	2.69
C. Grand Canary	2.06
D. Kano	3.15
E. Johannesburg (DSIF)	6.43
F. Zanzibar	5.50
G. Indian Ocean Ship	3.47
H. Muchea	3.94
I. Woomera (Remote)	3.47
J. Woomera (DSIF)	4.72
K. Mindanao	2.38
L. Canton Island	3.78
M. Kermadec Island	3.63
N. Kauai Island	2.85
O. Easter Island	3.31
P. Pacific Ocean Ship	1.91
Q. Point Arguello	2.85
R. Guaymas	4.09
S. White Sands	4.72
T. San Antonio	4.09
U. Houston (Remote)	4.69
V. Goldstone (DSIF)	4.56
W. Houston (MCC)	12.91
X. Eglin	3.31
TOTAL	100.00

APPENDIX A

GOSS STATIONS SELECTION

This appendix is presented in support of the General GOSS Configuration requirements of paragraph 3.2.3 of the specification proper. Graphical and computer methods were employed to determine coverage capability of established stations and to determine locations for new stations to satisfy requirements.

I. Evaluation of Coverage Capability of Mercury Network

The AMR stations provide the necessary coverage for the boost phases of the Apollo trajectories. The coverage for the orbital phase of circular orbits with 100, 156, and 200 n. mi. altitudes was evaluated by graphical methods, including the use of "Breckman Projection Charts." (1)

The coverage of two near-earth missions, each having orbital heights of 150 n. mi., was determined by use of a 7090 computer program developed at RCA Mooretown. Both missions were launched from Cape Canaveral; the first was launched on an azimuth of 75 degrees; the second on an azimuth of 105 degrees. Both had orbit inclinations of approximately 32 degrees. Each mission was continued for 20 orbits. The radar and telemetry coverage of all stations except the Cape Canaveral and Kauai, Hawaii were limited by a 5° horizon mask; the Cape Canaveral and Kauai stations were assumed capable of a zero degree capability for telemetry.

Plots of cumulative coverage per orbit were made and are shown in Figures A-1 and A-2. The first orbit starts with launch; subsequent orbits start with the northerly crossing of the equator. (2) The coverage of the first three orbits for the 75° launch is excellent for evaluating the status of the mission to go for the full mission, up to 14 days. The coverage of the first three orbits of the 105° launch is not as good and would not be a good launch azimuth for launching earth orbital missions. Lunar missions required to be launched on the latter azimuth would require increased coverage to refine the orbital data for lunar injection.

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(1) RCA, Theory and Use of B Charts by Jack Breckman, 2 January 1962.

(2) This orbit numbering system was used in lieu of a known standard employed by NASA.

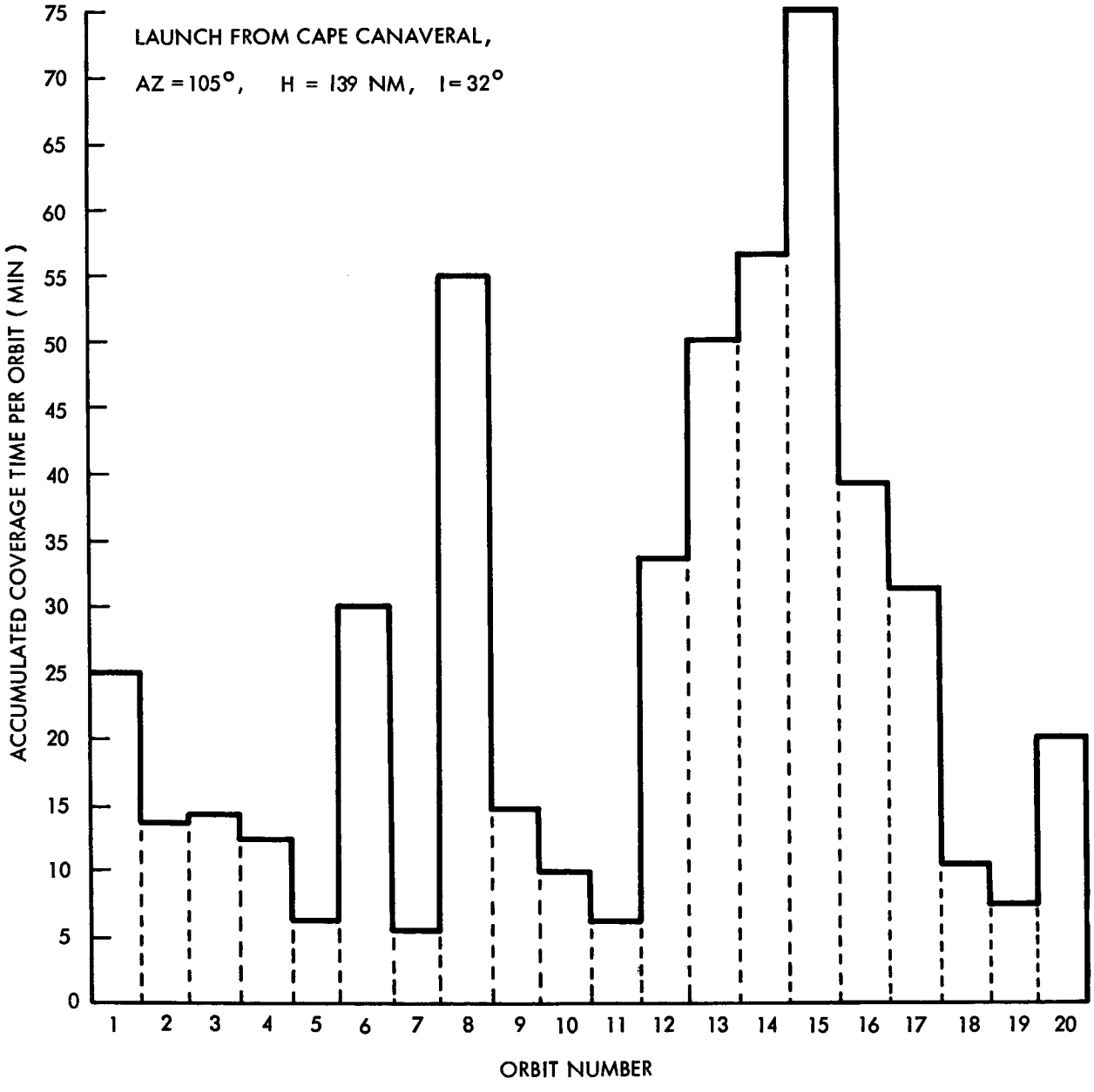

Figure A-1. Accumulated Coverage per Orbit by Mercury Network

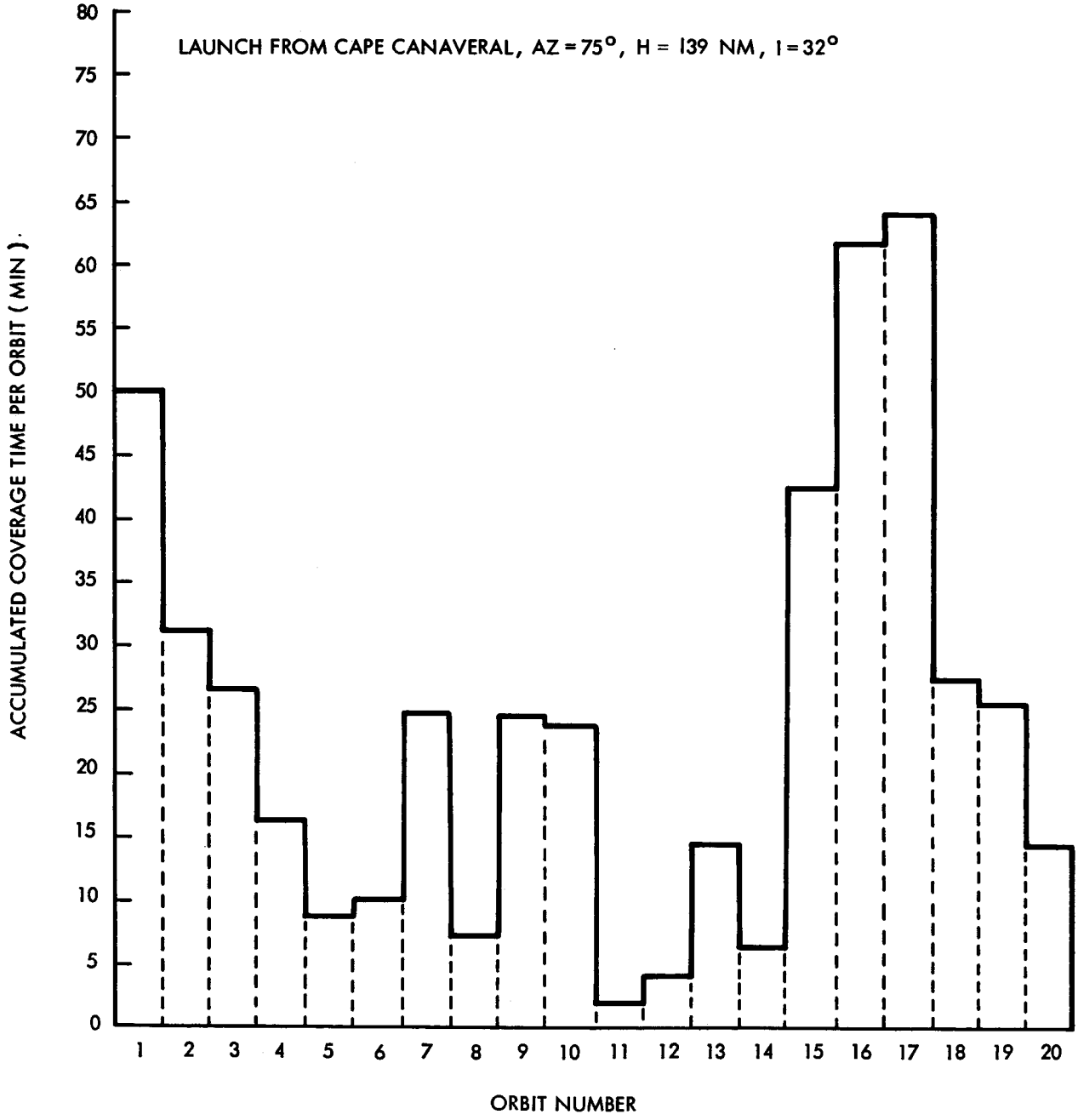

Figure A-2. Accumulated Coverage per Orbit by Mercury Network

Figures A-3 and A-4 present the maximum coverage gaps for the same orbits. In those cases where the gap includes the start of a new orbit, the gap is shifted to the ending orbit. These figures show that one gap in the 105° azimuth case exceeds the orbital period of approximately 90 minutes and several gaps in each case approach the period. However, the limitation of telemetry communications to a 5° horizon mask is overly conservative. Assumption of a zero degree horizon, supported by Mercury experience would reduce most of the gaps. Also, addition of a station near Mindanao (basically for purposes of alternate landing sites coverage) would reduce gaps of 4 to 6 orbits per day.

Thus, it is established that the Mercury Network can adequately support the earth orbital mission in regard to the requirement for a contact on every orbit.

II. Selection of the Alternate Landing Sites

The basic criterion for selection of alternate landing sites is that the spacecraft must be able to abort out of any orbit of the earth orbital missions into a landing site - the primary, the secondary or one of the alternate landing sites.

With the spacecraft capability for de-orbiting out of three successive orbits into any landing site located at 29.48° latitude (N or S), an ideal group of alternate landing sites would be located as follows:

For orbits between 100 and 200 n. mi., there are approximately 16 orbits per day. Then, if all 16 orbits are to get into a landing site, 5 plus ($16 \div 3$), hence, 6 landing sites would be required to be approximately distributed. Assuming the use of San Antonio, the ideal distribution would be to space the 5 more sites along the 29.48° N latitude at intervals of 60° ($360 \div 6$) from San Antonio.

These would be located as follows:

1. 29.48° N. latitude, 39.00° W. longitude, in North Atlantic Ocean
2. 29.48° N. latitude, 21.00° E. longitude, in North Africa
3. 29.48° N. latitude, 81.00° E. longitude, in Northern India
4. 129.48° N. latitude, 141.00° E. longitude in the Pacific Ocean, off Japan
5. 29.48° N. latitude, 159° W. longitude in the Pacific Ocean, north of Hawaii

CONFIDENTIAL

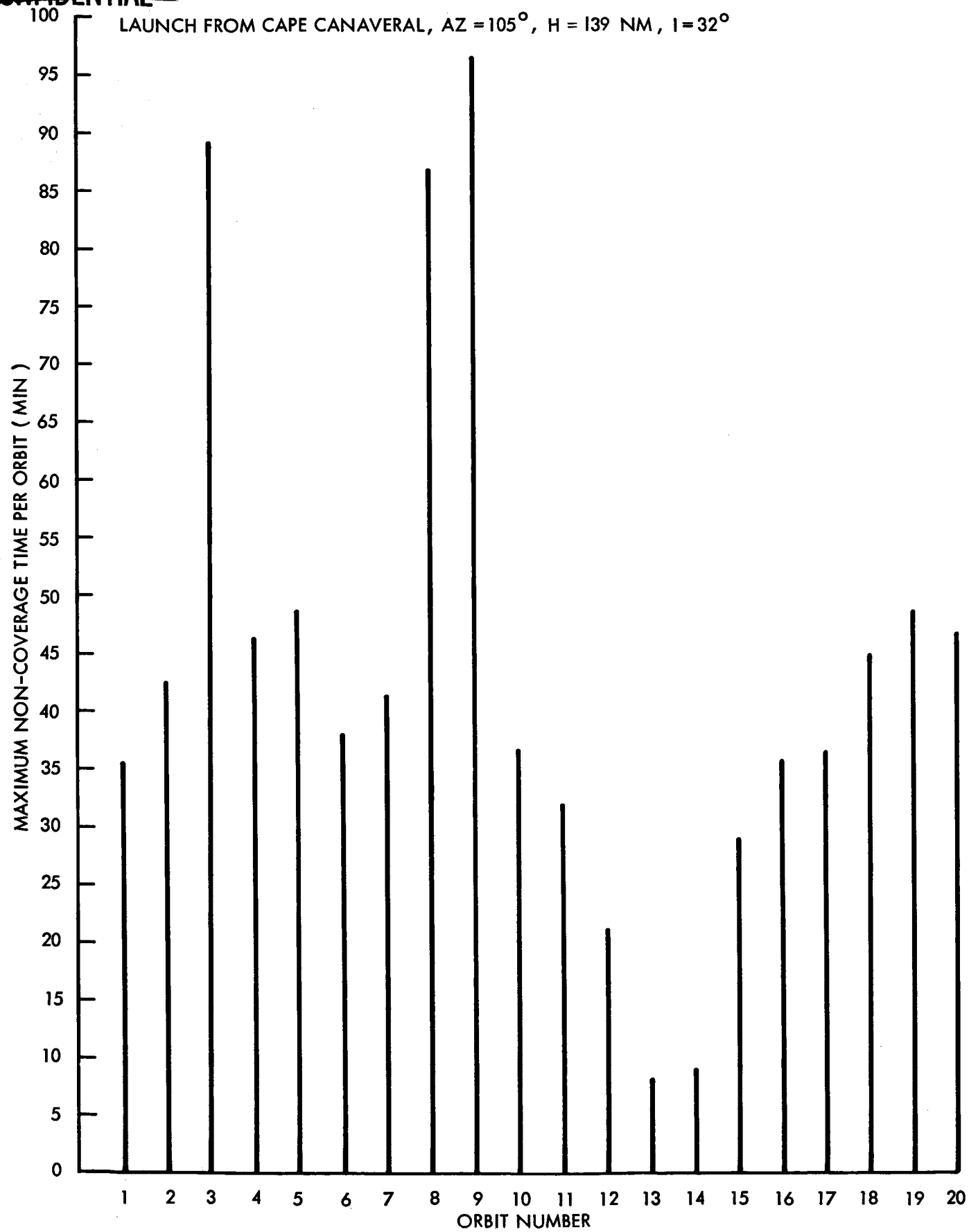

Figure A-3. Maximum Non-Coverage Time per Orbit by Mercury Network

CONFIDENTIAL

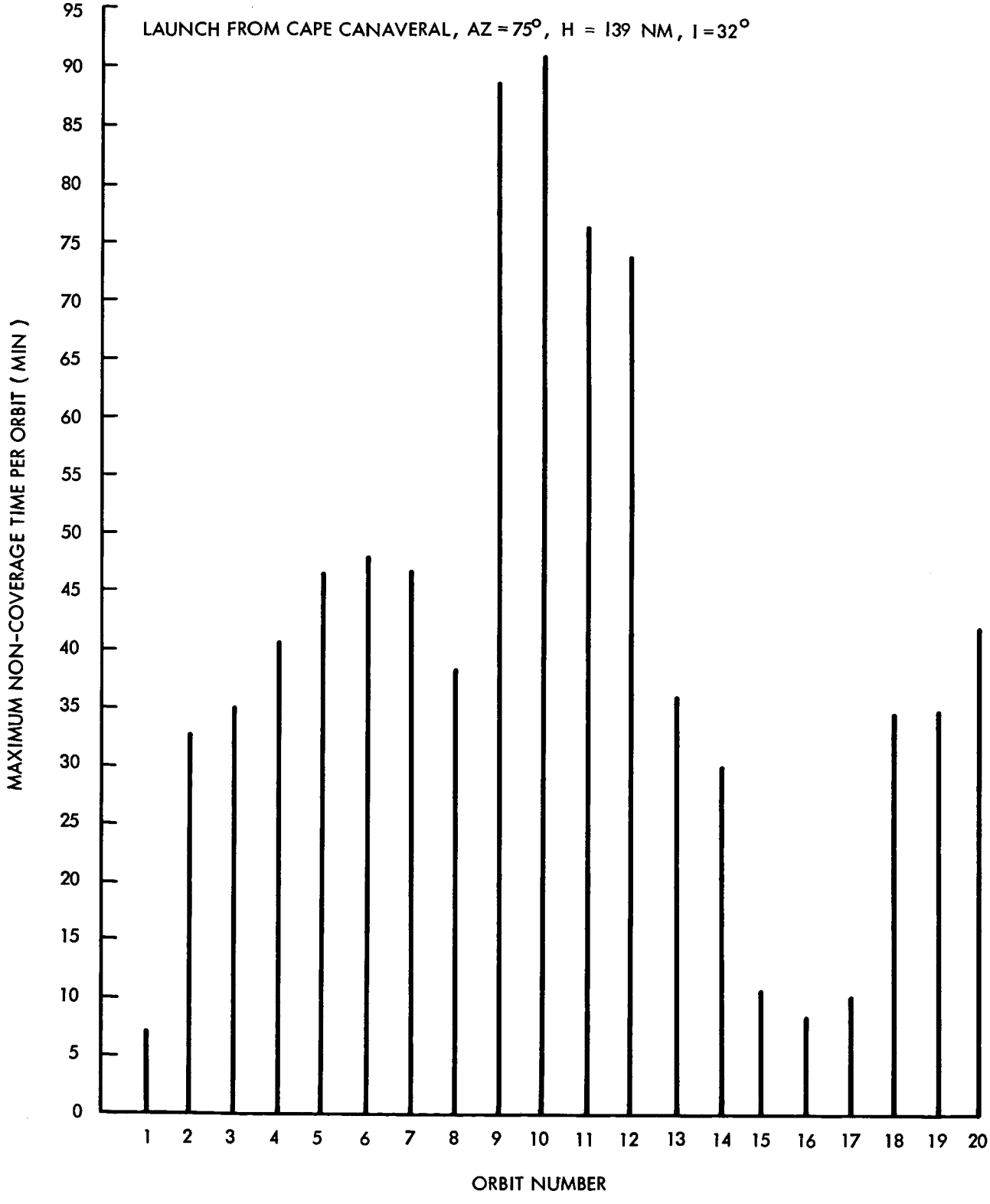

Figure A-4. Maximum Non-Coverage Time per Orbit by Mercury Network

These 6 sites would provide a slight redundancy; they could be as far apart as 66 degrees of longitude and be satisfactory.

Two of these, North Africa and Northern India are considered unsatisfactory for geographical and political reasons. These are respectively replaced by sites as follows:

1. 29.48° S latitude, 170.00° S longitude, in the South Pacific Ocean east of the Kermadec Islands

2. 29.48° S latitude, 110.00° W longitude, in the Southeast Pacific Ocean near Easter Island.

The orbits that can land at the original two sites can land at these, respectively, since they are in a corresponding position with regard to these same orbits.

These two new sites are themselves undesirable as regards their logistic support; however, they are more reasonable overall than the two they replace.

The site in the North Atlantic is redundant as a result of the prior selection of Woomera as the secondary site and is therefore deleted.

Analysis of the coverage of the ejection, de-orbit coast, and entry phases of landings at the resultant landing sites leads to one more substitution.

San Antonio - As primary landing site, coverage will be provided.

Woomera - The Indian Ocean Ship and Muchea provide adequate coverage.

Hawaii - No coverage exists, but this ideal location warrants providing coverage for it. A fully equipped site near the southern tip of Mindanao (probably a ship) would serve both Hawaii and the Kermadec Islands landing sites.

Kermadec Islands - Imperfect coverage provided by Mindanao and Woomera.

Easter Island - Reasonably good coverage would be provided by radar at Canton and at the Kermadec Islands landing site.

Japan - No coverage exists.

Coverage for the site off Japan could be provided by a ship station off the southern tip of India. This station would contribute little else to the coverage requirements of the various Apollo missions.

By contrast, the substitution for the Japan site of a landing site at 29.48° S latitude, 45.00° W longitude in the South Atlantic, results in a more favorable situation. Radar at the Easter Island landing site would provide some coverage, while a ship station at approximately 12.00° S latitude, 110.00° W longitude would provide earlier, more complete coverage and be in position to be used more conveniently to satisfy the varying coverage requirements of Apollo missions.

For example, for lunar missions the GOSS must be prepared to support long earth orbital missions carried out as alternate missions in the situation where a lunar mission aborts prior to injection into the translunar phase. Thus, at the mission outset, the ship station coverage of the South Atlantic site would be in place. After the successful injection into the translunar phase, this ship could proceed into position to support the return of the spacecraft to San Antonio. Six to fourteen days would be available for movement of about 2,000 miles toward Canton or Hawaii. For this reason, the South Atlantic site is preferred over the site off Japan.

APPENDIX B

RADAR ASPECTS OF APOLLO

Introduction

The sensors to be available to Apollo will be in part those of the Mercury-Gemini net and in part additional equipments to be added to present stations or to instrument new stations.

Three sensor operational regions may be identified.

a. The near-earth region in which the primary limitations are the earth curvature and atmospheric effects.

b. A medium-range region in which the accuracy of position and velocity data is satisfactory when derived from a single radar or single station.

c. An extreme-range region in which the accuracy of a single radar or station is marginal or unsatisfactory because of uncertainties or errors in angle measurement.

The functions and performance requirements of the radars in each of these regions are discussed in following paragraphs.

Coverage

An orbital altitude of 100 n. m. requires a radar range of about 600 n. m. for a 5-degree horizon. Higher altitudes require larger ranges.

The C-band radar presently being used in Mercury has an unambiguous range of 500 n. m. This limitation can be decreased by simple modification which should be accomplished.

Acquisition

The passage of the spacecraft from one radar station to the next requires successive acquisitions by the radars. This occurs more frequently in the near-earth region but also occurs during space flight. The problems associated with acquisition are primarily in knowing the position, velocity, and time of the vehicle when it appears within the coverage of the radar.

Thus if the orbital elements are given accurately, the radar can be "waiting" for the vehicle and acquisition is very rapid. However, if this is not the case, then a search must ensue. As an example, for an orbit of 200 n. m. altitude which is tracked for a large part of the time while in the coverage, say about 200 seconds, with a radar of $\sigma = 0.01$ degree angular accuracy, the error in the period would be about 4 seconds. Such an error (0.01 degree) would result in an error normal to the orbit of about 2 miles after one orbit. The error normal to the orbit defines the area to be searched by the radar beam. Since there is also an uncertainty in time of arrival, a larger volume must be scanned to guarantee its acquisition. To assist in this process it is desirable to have direct links between adjacent stations so that the first radar can directly assist in the acquisition by the second radar. The generally adequate signal-to-noise ratio (SNR) in the near-earth region would also permit an increase in the beam size to reduce or eliminate the search.

The station next past the one in which insertion into orbit occurs will experience the most difficulty. This station could be handled in a special way to assist in acquisition. The same situation would also arise in the reentry phase and this station, too, could be given special handling. In addition, in the period prior to the unified frequency implementation, the broader beam VHF facilities could be used to assist the narrower beamed radar. At those stations where coverage overlaps, the fact that the transponder is already being triggered will further assist in acquisition.

Acquisition by the DSIF radars from the Mercury radars is in general the same type of problem. For a condition of adequate SNR the amount of search required will decrease with increased range of the vehicle.

Radar Requirements

The near-earth region can be further broken down. Thus the radar requirements during launch are different from those after the orbit has been achieved. For example, the angular velocity and acceleration are much higher during launch than in orbit. Similarly, reentry and abort impose different demands on the radar. Skin tracking, for example, may be required because of beacon blackout. This is an important problem and must be studied for a satisfactory solution.

The shipboard radars must be able to operate with data that is not as accurate as the rest of the net due to the inexactness of the ship's location. The ship's motion imposes further requirements.

Radar Functions

In each of the three regions, the requirements on the radars are determined by the function which must be performed. They are in part:

a. Launch

b. Range safety

c. Injection into orbit

d. Determination of orbit

e. Determination of vehicle position in orbit

f. Injection into cislunar orbit

g. Determination of cislunar orbit

h. Determination of vehicle position in orbit

i. Prediction of time for course correction

j. Determination or corrected orbit and further corrections if required

k. Injection into circumlunar orbit

l. Necessary commands for return orbit

m. Reentry commands

n. Determination of impact

o. Communications two-way

p. Telemetry.

Near-Earth Region

The near-earth region is distinguished from the other two regions by the necessity for more rapid scan and acceleration of the antenna. In this region a higher SNR is available, thus permitting smaller and lighter antennas. Transmitter power required is not excessive in this region due to

the smaller free space attenuation. However, these are somewhat compromised by the requirement for a broad beam antenna in the vehicle due to the large range of aspect angle. As an alternative to maintain the advantage in this region, the vehicle could use a high gain antenna which must be oriented in the proper direction. This is an undesirable alternative.

In this region it would also be desirable, when the unified frequency equipment becomes available, to control its transmitter power as a function of range to prevent saturation of the transponder. The gain of the receivers in the radar should have a similar control. This will also reduce the dynamic range and AGC requirements.

In this region the radar should probably have skin track capability. Although this capability might be desirable everywhere for greater overall reliability, its cost may be prohibitive.

Medium-Range Region

In this region the angular accuracy available from a single radar is still adequate. Normally, it would be expected that the velocity and acceleration capabilities of the antenna can be greatly reduced. However, under the unified frequency concept, the multiple functions required of the radar will impose the most stringent requirements upon its performance. Thus, in this region where greater antenna size is desirable for improved angular accuracy (and SNR if needed), the greater agility needed in the near-earth region must also be met. At this point the advantages become evident of beam broadening for acquisition (by beam spoiling) without surrendering the advantage of a large dish when it is needed later.

For an accuracy of $\sigma = .1$ mil, the tangential error at a range of 10^5 n. m. is 10 n. m. This error now is considerably larger than the range error which is available from most radars designed for lunar missions. The angular rate error will also be proportional to the angular error. In general, angular rate errors are predominant in determining accuracy of impact. Thus it would be desirable to use a system which attempted to maintain the same tangential error in angle as is available in range and perhaps an angular rate error which is in the order of the range rate error. Since the angular rate error does not improve with range for orbits which are moving approximately radially, some other technique must be found. This is not to say that the angular accuracy is not adequate or that other techniques for determining angular velocity cannot be used. It simply means that eventually a limit is reached where angular rate error becomes unsatisfactory when determined from angular data.

Extreme-Range Region

The need for more accurate position and velocity data in the extreme range region indicates that a triangulation system using DSIF type stations is desirable. This could be accomplished by adding DSIF stations in regions of comparable longitude and opposite latitude to the present DSIF stations. This technique provides north-south baselines which complement the existing east-west baselines to provide more accurate determination of spacecraft position. Although the problems associated with multiple stations are not all solved, they appear to offer considerable improvement over single stations.

It is also in this region that the system becomes limited in SNR. The factors contributing to this are primarily the power in the transponder, the gain of the vehicle antenna, the size of the radar antenna and the noise figure of the receiver. Each of these parameters has limits beyond which improvement is exceedingly costly, or in the case of noise, presumably impossible. Perhaps the most easily improved would be the antenna area of the radar. When the area required exceeds the practical size for a single dish it is possible to add separate dishes and to use techniques of radio astronomy.

Performance Requirements

It should be noted that there are in the GOSS, at present, equipments that are not compatible with the unified frequency concept. In some instances they may be modified to operate with the unified frequency; other equipments will have to be discarded. Where new equipments have to be added, compatibility with the unified frequency concept should be required.

At this time it is not possible to specify completely the performance requirements of the radars. Some requirements involve further systems studies and in other cases basic research is necessary.

Range

Hemispherical coverage is desirable, although it is not required at all stations. Operation down to the horizon is also usually not necessary. For an orbital altitude of 200 n.m., a range of about 1200 n.m. is required at this horizon. If a lower elevation limit of 5 degrees is introduced, the range is reduced to about 950 n.m. Since range is easily achieved in a cooperative(beacon or transponder) system, the 1200 n.m. range is perferable. Some of the radars which are used in earth orbit could also be used, after modifications, as part of the DSIF. Their range must now be at least 210,000 miles. Achieving this range unambiguously depends upon the modulation used and is not too costly. However, since the vehicle is under almost complete surveillance, a log of its range could be maintained so that an ambiguous system is permissible.

Angular Velocity and Acceleration

The requirement for acquisition determines the highest angular velocity and acceleration. It also appears that reentry and abort situations are the most difficult to handle. The "worst case" conditions for both of these must be studied. For az - el antenna pedestals the zenith pass must also be studied.

Antenna Gain

The antenna gain is determined primarily by the angular accuracy required in the near-earth region and by it and the receiving area in the deep space region. A lower limit on size might be imposed by multipath, especially for the shipboard radars. An upper limit is reached when the accuracy of the surface can no longer be maintained for the desired frequency. It should be noted that the antenna gain is the only parameter which can be varied to give equal variations in SNR in the vehicle and the radar.

Power

The power requirements are highly dependent upon the amount of information which is transmitted to the vehicle. A satisfactory SNR must be maintained in the sidebands. If ability to skin track during abort or reentry is required, the power is fixed by this capability. However, for operation with a transponder the same SNR can be obtained in the transponder and in the radar when the transmitter power is the same in both transponder and the radar (this assumes equal modulation conditions at both ends).

Polarization

An orthogonal polarization feed is required. This is determined by both the wide variation of the attitude of the vehicle with respect to the radar and the Faraday rotation of the ionosphere.

Receivers

The tremendous ratio of maximum range to minimum range over which the radar must operate indicates a requirement for possibly a combination of STC, large dynamic range, and AGC. In addition, phase and amplitude tracking in the error channels is critical for stability in a narrow beam antenna. It is also required for an error correction system in which error voltages are applied as corrections to angular position. Since range rate information exists in the received signal in the form of doppler, this information should be extracted. The receiver should also be capable of operating in phase-lock in order to maintain high SNR with transponder instability.

Frequency

Previous studies have indicated a preference for the high end of the UHF band. This appears to be satisfactory from considerations of ionospheric effects and for generation of large power. The power in this case is only required for use in skin-track or where large amounts of information must be transmitted to the vehicle. However, if the latter two factors are not strong, then a higher frequency would appear to be more economical from considerations of antenna size in both vehicle and radar.

Accuracy

The accuracy of the radar should be as high as possible. However, it is always obtained at a price and involves a trade-off. Thus, singular accuracy which requires a narrow beam is achieved at the expense of a larger dish and greater difficulty in acquisition. Range accuracy is achieved only at the expense of less SNR because of the greater band width. A common factor in all accuracy requirements is the improvement with increased power.

Operation in Passive and Active Modes

Multi-site operation is achieved at small expense in the case of active radar operation. The sites are already there (assuming the equipment is suitable) and data is obtained in a normal way (with provision made for eliminating unwanted signals). In this case the transponder peak power must be reduced to maintain the same average. The increased accuracy that may be achieved in position and velocity would appear then to warrant this. In passive operation the problem is more complicated but the transponder is simplified. Both modes of operation require consideration.

Data In and Out

Each radar must be capable of receiving data from the system. Thus, acquisition data from the MCC or other points must be translated into angular and range coordinates. Similarly, commands to the vehicle originating locally or externally must be transformed into the equivalent modulation on the carrier. In reverse, the measured position data and intelligence data must be converted into a form for required external transmission or internal processing.

Radar Utilization

The basic problem concerning radar utilization is whether or not to use both C-band and S-band radar beacon systems aboard the spacecraft.

Preliminary investigation of the problem indicates that it is more desirable to use a C-band beacon system exclusively. Some of the aspects of the problem are the following:

1. Spacecraft onboard equipment weight

2. Ability to acquire the spacecraft

3. Remote station radar availability.

The first aspect, that of onboard spacecraft equipment weight, is probably the most important consideration. Equipment weight is, and probably will continue to be a very critical problem area. It is felt that any equipment redundancy for improving reliability should be incorporated into one beacon system rather than into two beacon systems operating on different frequencies.

The contemplated use of a small data processor at each remote station will increase the acquisition capability of the radar. Orbital parameters furnished by the MCC will be converted into continuous look angles by the remote station data processor. These continuous look angles, plus the use of several search patterns programmed into the radar computer, are expected to provide the desired early lock-on by the C-band radars.

At present, the basic Mercury network consists of 10 stations with radar capability. There are three stations with both C-band and S-band radar capability, four stations with C-band only, and three stations with S-band only.

Several new stations are being recommended for the GOSS network and C-band radars are proposed for these stations. The majority of stations would then have C-band capability. The cost of installing C-band radars at the three sites now having only S-band radars involves appreciable additional cost. This cost must be evaluated by comparison with the weight penalties involved in adding an S-band beacon in the spacecraft.

Integrated Communications Concept

The integration of essentially all spacecraft-to-ground tracking and communication functions into a common operating frequency by time and frequency multiplexing is seen to be a feasible spacecraft-GOSS operating mode. The recovery communications equipments will not be a part of the integrated communications.

Preliminary results of a study at S&ID indicate that implementing the concept for the Apollo GOSS can provide a saving of several million

dollars to the program compared to the continued development and implementation of the present concept which employs separate frequencies for separate functions. The savings appear in the reduction of development costs for spacecraft electronics, and the reduction of costs in modifying the GOSS network. A very significant reduction in spacecraft communications equipment weight is also realized.

The integrated communications concept results in the following types of equipment being used. The existing DSIF will be the basic building block. The spacecraft DSIF transponder will provide the on-board tracking and communications functions, except for recovery communications. The three 85-foot antenna DSIF stations satisfy all cislunar and lunar requirements including real time television. Remote stations concerned with tracking and communications during earth-orbital missions require 18-ft diameter antennas to provide the desired tracking accuracy. Those remote stations which are limited to communications support during earth-orbital missions require 6-ft diameter antennas.

APPENDIX C

RELIABILITY MATHEMATICAL MODEL AND APPORTIONMENT PROCESS

A. Introduction. - Application of the Calabro * availability model should assure the responsible contractor more stringent control of maintenance action rates, inherent maintenance design capability, logistic capability, and maintenance time constraints.

a. Availability reapportionments would be required periodically until the geographical location, responsibilities, and criticality of each ground station is firmly established.

b. Availability estimates for existing Mercury stations (which are to be considered in the Apollo program) would be required so that upgrading, where necessary, of equipment, spares, maintenance capabilities, and maintenance time constraints could be effected.

c. As demonstrated by this Appendix, extreme station availability values would be required; however, this study has considered a typical worst case analysis such that every point in time was included for all GOSS functions including ground-to-ground and ground-to spacecraft communications.

d. The enhancement of reliability is provided by establishing a minimum maintainability level for each ground station. This level establishes each station's lower availability limit. When the contribution of an effective maintenance program is added to the station reliability, the apportioned station availability value is again placed in the realm of reality and achievement.

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* The mathematical model chosen for availability was developed by S. R. Calabro, Director, Product Assurance Division, International Electric Corporation (Reference Reliability Principal and Practices, McGraw-Hill, 1962). This text, selected by Dr. H. G. Romig, is presently included in the curriculum for Reliability Engineering at the University of Southern California.

B. Availability Apportionment for the GOSS Complex

a. Ground Station. - Ground station availability is expressed by the following model:

$\Delta E = 1 - \exp(-ut) - \exp(-(ut + rT))$

$\Delta E = 1 - \exp(-ut)\,(1 - \exp(rT))$

ΔE = Ground Station Availability

ϕ = Total Maintenance - Action Time in Hours / Number of Maintenance-Actions

$\mu = \frac{1}{\phi}$

μ is defined as maintenance-action rate/hr.

t = Maintenance Time Constraint

r = failures /hr

T = Operating time for station to complete specified functions with spacecraft and GOSS Complex

b. GOSS. - GOSS availability for a typical Lunar mission, Launch Pad to Earth Recovery, is equal to:

$\Delta E_T = \Delta E_1 \cdot \Delta E_2 \cdot \cdot \cdot \Delta E_n$

ΔE_T = Total GOSS Availability for a Typical Lunar Mission

ΔE_1 = Launch-Pad Availability

ΔE_n = Earth Recovery Availability

c. Definitions. -

a. Station availability is the probability that a stated percentage of equipment will be available for use at time T due to the combined effect of surviving equipment and equipment restored to service through maintainability in a time equal to, or less than, the time constraint t.

b. The term $\exp-\mu t$ represents the probability of performing zero maintenance action in time t. The expression, $1 - \exp(-rt)$ represents the probability of failure in time T. The product of these two expressions is the

probability of not being able to restore the inoperative units to use; when this probability product is then subtracted from unity, what remains is ΔE, the station availability.

d. Mission Phase. - The GOSS performance reliability has been specified as being no less than 0.999. (Paragraph 4 of specification). An availability apportionment for a typical Lunar mission was determined for each mission phase. Station criticality and complexity provided the basis for this apportionment for the following phases: Pre-Launch, 1st & 2nd Stage Boost, Earth Orbit (No. 1, 2, 3), Inject to Trans-Lunar, Re-Entry, Earth Landing, and Recovery. Station criticality and performance time provided the apportionment basis for these phases: Trans-Lunar, Lunar Orbit and Landing, Lunar Exploration, Lunar Launch, Lunar Orbit, Injection to Trans-Earth, and Trans-Earth. The step-by-step procedure is as follows:

(Ref. Tables C-I, C-II, and C-III)

1. Identify the major mission phases.
2. Determine the relative station weights as applicable for criticality, complexity, and performance time for each mission phase. A matrix array which includes applicable ground stations per mission phase is used for establishing station preference for each qualitative variable. The resulting inequality which defines the station preferences is next expressed in probability values. Then the probability values are weight-scaled (1- 4) and the appropriate weight is assigned to each mission phase - station cell.
3. Total the cell weights for the matrix.
4. Sum the weights for each cell.
5. Divide the weight sum of each cell by the total matrix weight. This quotient is called the Availability Budget Factor.

$$\text{Availability Budget Factor (i j'th cell)} = \frac{\sum_{m} W \text{ i j'th cell}}{\sum_{i=1}^{n}\sum_{j=1} W \text{ i j'th cell}}$$

W = assigned weight for each qualitative variable

6. Raise the base reliability 0.999 for each cell to the power indicated by the Availability Budget Factor in Step 5.

7. Sum the product of each mission phase availability for each station.

$$\Delta S = \prod_{j=1}^{m} p_{ij}$$

ΔS defines any station availability for the phase interval $j = 1$ to $j = m$.

8. Sum the product of each station availability for each mission phase.

$$\Delta p = \prod_{i=1}^{n} p_{ij}$$

Δp defines any mission phase availability for station invervals $i = 1$ to $i = n$.

9. Sum the product of all station availabilities.

$$\Delta S_T = \prod_{i=1}^{n} \Delta S$$

10. Sum the product of all mission phase availabilities

$$\Delta p_T = \prod_{j=i}^{m} \Delta p$$

11. The product sum of Step 9 must equal the product sun of Step 10.

$$\Delta S_T = \Delta p_T = \prod_{\substack{i=1 \\ j=1}}^{\substack{n \\ m}} p_{ij}$$

e. Probability of Crew Survival Apportionment. - Crew survival probabilities are apportioned in a manner similar to paragraph B-d

except the base reliability (reference paragraph B-d step 6) is 0.99999.

f. Apportionment Ground Rules.- A Lunar mission, earth launch time 1540 GMT 3 August, 1965 was chosen for this availability apportionment study as a reference flight plan.

g. The ground stations were assumed to be series elements during any given phase except that redundancy effects were considered for the DSIF stations when making weight apportionments.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	
A		+1	+1	+1	0	+1	+1	+1	+1	0	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	0	0	+1	+19
B	-1		+1	+1	0	+1	+1	+1	0	0	0	+1	+1	0	+1	+1	0	+1	+1	+1	+1	0	-1	+1	+11
C	-1	-1		+1	-1	+1	+1	+1	0	-1	+1	+1	+1	0	+1	+1	0	+1	+1	+1	+1	-1	-1	+1	+8
D	-1	-1	-1		-1	0	-1	-1	-1	-1	-1	-1	0	-1	0	-1	-1	-1	0	-1	-1	-1	-1	0	-18
E	0	0	+1	+1		+1	+1	+1	+1	0	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	0	0	+1	+18
F	-1	-1	-1	0	-1		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	-1	-1	-1	-1	-20
G	-1	-1	-1	+1	-1	+1		0	-1	-1	0	0	+1	0	+1	+1	-1	+1	+1	+1	+1	-1	-1	+1	+1
H	-1	-1	-1	+1	-1	+1	0		0	-1	-1	0	+1	-1	+1	-1	-1	+1	+1	+1	+1	-1	-1	0	-3
I	-1	0	0	+1	-1	+1	+1	0		-1	-1	-1	+1	-1	+1	+1	-1	+1	+1	+1	+1	-1	-1	+1	+2
J	0	0	+1	+1	0	+1	+1	+1	+1		+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	0	0	+1	+18
K	-1	0	-1	+1	-1	+1	0	+1	+1	-1		+1	+1	0	+1	+1	0	+1	+1	+1	+1	-1	-1	+1	+7
L	-1	-1	-1	+1	-1	+1	0	0	+1	-1	-1		+1	-1	+1	0	-1	+1	+1	+1	+1	-1	-1	+1	0
M	-1	-1	-1	0	-1	+1	-1	-1	-1	-1	-1	-1		-1	0	0	-1	0	+1	-1	+1	-1	-1	+1	-11
N	-1	0	0	+1	-1	+1	0	+1	+1	-1	0	+1	+1		+1	+1	0	+1	+1	+1	+1	-1	-1	+1	+8
O	-1	-1	-1	0	-1	+1	-1	-1	-1	-1	-1	-1	0	-1		-1	-1	0	0	0	-1	-1	-1	+1	-14
P	-1	-1	-1	+1	-1	+1	-1	+1	-1	-1	-1	0	0	-1	+1		-1	+1	+1	+1	+1	0	0	+1	-3
Q	-1	0	0	+1	-1	+1	+1	+1	+1	-1	0	+1	+1	0	+1	+1		0	+1	+1	+1	-1	-1	+1	+8
R	-1	-1	-1	+1	-1	+1	-1	-1	-1	-1	-1	-1	0	-1	0	-1	0		+1	+1	-1	-1	-1	+1	-10
S	-1	-1	-1	0	-1	0	-1	-1	-1	-1	-1	-1	-1	-1	0	-1	-1	-1		0	-1	-1	-1	-1	-19
T	-1	-1	-1	+1	-1	0	-1	-1	-1	-1	-1	-1	-1	-1	0	-1	-1	-1	0		-1	-1	-1	-1	-16
U	-1	-1	-1	+1	-1	+1	-1	-1	-1	-1	-1	-1	-1	-1	+1	-1	-1	+1	+1	+1		-1	-1	+1	-9
V	0	0	+1	+1	0	+1	+1	+1	+1	0	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1		0	+1	+18
W	0	+1	+1	+1	0	+1	+1	+1	+1	0	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	0		+1	+19
X	-1	-1	-1	0	-1	+1	-1	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	+1	+1	-1	-1	-1		-15
	-19	-11	-8	+18	-18	+20	-1	+3	-2	-18	-7	0	+11	-8	+14	+3	-8	+10	+19	+16	+9	-18	-19	+15	

A=W>E=V=J>B>C=N=Q>K>I>G>L>P>H>U>R>M>O>X>T>D>S>F

NOTES

1. Station Code

   A. Cape Canaveral
   B. Bermuda
   C. Grand Canary
   D. Kano
   E. Johannesburg
   F. Zanzibar
   G. Indian Ocean Ship
   H. Muchea
   I. Woomera (remote)
   J. Woomera (DSIF)
   K. Mindinao
   L. Canton Island
   M. Kermadec Islands
   N. Kauai Island
   O. Easter Island
   P. Pacific Ocean Ship
   Q. Pt. Arguello
   R. Guaymas
   S. White Sands
   T. San Antonio
   U. Houston (Remote)
   V. Goldstone (DSIF)
   W. Houston (MCC)
   X. Eglin

2. Qualitative information has been put into the matrix on the basis of Mercury Network experience.

3. a. Any row station is defined as "i"
   b. Any column station is defined as "j"
   c. When the criticality of i>j the ij^{th} cell is +1.
   d. When the criticality of i<j the ij^{th} cell is -1.
   e. When the criticality of i=j the ij^{th} cell is zero (0).
   f. When the criticality of i compared to j is unknown, a zero (0) is assigned to the ij^{th} cell.

Table C-I

		PRE-LAUNCH	1ST & 2ND STAGE BOOST	#1	EARTH ORBIT #2	#3	INJECT TO TRANS-LUNAR	TRANS-LUNAR	LUNAR ORBIT & LANDING	LUNAR EXPLORATION	LUNAR LAUNCH	LUNAR ORBIT	INJECT TO TRANS-EARTH	TRANS-EARTH	RE-ENTRY	EARTH LANDING	RECOVERY	ROW (i) WEIGHT TOTALS
A CAPE CANAVERAL	W	4, 1	4, 1	4, 1	4, 1	4, 1	4, 1										4, 1	35
	X	.0078125	.0078125	.0078125	.0078125	.0078125	.0078125										.0078125	
B BERMUDA	W	2, 1	1, 2	1, 1	2, 1	2, 1	2, 1											17
	X	.0046875	.0046875	.0031250	.0046875	.0046875	.0046875											
C GRAND CANARY	W	2, 1	1, 4	1, 1	2, 1													13
	X	.0046875	.0078125	.0031250	.0046875													
D KANO	W	1, 4		1, 4	1, 4		1, 4											20
	X	.0078125		.0078125	.0078125		.0078125											
E JOHANNESBURG (DSIF)	W	4, 1					4, 1	(4), 3	(2), 4	(4), 2				(4), 3	4, 1			41
	X	.0078125					.0078125	.0110938	.0093750	.0093750				.0110938	.0078125			
F ZANZIBAR	W	1, 4		1, 4	1, 4		1, 4								4, 1	1, 4	1, 4	35
	X	.0078125		.0078125	.0078125		.0078125								.0078125	.0078125	.0078125	
G INDIAN OCEAN SHIP	W	2, 1		1, 2	2, 1		2, 2								2, 1	2, 1	2, 1	22
	X	.0046875		.0046875	.0046875		.0062500								.0046875	.0046875	.0046875	
H MUCHEA	W	2, 4		1, 2	2, 1	2, 2									2, 1	2, 1	2, 1	25
	X	.0093750		.0046875	.0046875	.0062500									.0046875	.0046875	.0046875	
I WOOMERA (REMOTE)	W	2, 2		1, 1	2, 1		2, 2								2, 1	2, 1	2, 1	22
	X	.0062500		.0031250	.0046875		.0062500								.0046875	.0046875	.0046875	
J WOOMERA (DSIF)	W	4, 1						(3), 4	(2), 4	(3), 4				(3), 4	4, 1			37
	X	.0078125						.0110738	.0093750	.0110938				.0110938	.0078125			
K MINDINAO	W	2, 1					2, 1								2, 1	2, 1	2, 1	15
	X	.0046875					.0046875								.0046875	.0046875	.0046875	
L CANTON ISLAND	W	2, 1		1, 1	2, 1	2, 1	2, 2								2, 1	2, 1	2, 1	24
	X	.0046875		.0031250	.0046875	.0046875	.0062500								.0046875	.0046875	.0046875	
M KERMADEC ISLAND	W	2, 4		1, 4											2, 2	2, 2	2, 2	23
	X	.0093750		.0078125											.0062500	.0062500	.0062500	
N KAUAI ISLAND	W	2, 1			2, 1	2, 1									2, 1	2, 1	2, 1	18
	X	.0046875			.0046875	.0046875									.0046875	.0046875	.0046875	
O EASTER ISLAND	W	2, 4													2, 3	2, 3	2, 3	21
	X	.0093750													.0078125	.0078125	.0078125	
P PACIFIC OCEAN SHIP	W	2, 1													2, 1	2, 1	2, 1	12
	X	.0046875													.0046875	.0046875	.0046875	
Q PT ARGUELLO	W	2, 1			2, 1	2, 1									2, 1	2, 1	2, 1	18
	X	.0046875			.0046875	.0046875									.0046875	.0046875	.0046875	
R GUAYMAS	W	2, 4			2, 2	2, 2									2, 2	2, 2	2, 2	26
	X	.0093750			.0062500	.0062500									.0062500	.0062500	.0062500	
S WHITE SANDS	W	1, 4			1, 4	1, 4									1, 4	1, 4	1, 4	30
	X	.0078125			.0078125	.0078125									.0078125	.0078125	.0078125	
T SAN ANTONIO	W	1, 4			1, 3	1, 4									1, 3	1, 3	1, 3	26
	X	.0078125			.0062500	.0078125									.0062500	.0062500	.0062500	
U HOUSTON (REMOTE)	W	2, 3			2, 2	2, 2	2, 3								2, 2	2, 2	2, 2	30
	X	.0078125			.0062500	.0062500	.0078125								.0062500	.0062500	.0062500	
V GOLDSTONE (DSIF)	W	4, 1						(1), 1	(4), 1	(2), 1	(1), 1	(2), 1	1	(2), 1	4, 1			29
	X	.0078125						.0031250	.0078125	.0046875	.0031250	.0046875	.0015625	.0046875	.0078125			
W HOUSTON (MCC)	W	4, 1	4, 1	4, 1	4, 1	4, 1	4, 1	(4), 1	(4), 1	(4), 1	(4), 1	(4), 1	(4), 1	(4), 1	4, 1	4, 1	4, 1	80
	X	.0078125	.0078125	.0078125	.0078125	.0078125	.0078125	.0078125	.0078125	.0078125	.0078125	.0078125	.0078125	.0078125	.0078125	.0078125	.0078125	
X EGLIN	W	1, 4			1, 3	1, 3										1, 3	1, 3	21
	X	.0078125			.0062500	.0062500										.0062500	.0062500	
COLUMN (j) WEIGHT TOTALS		107	18	39	62	48	51	21	22	21	7	8	6	22	75	64	69	640

CELL WEIGHT CODES: COMPLEXITY n
CRITICALITY n
PERFORMANCE TIME (n)

W = ASSIGNED WEIGHT FOR EACH QUALITATIVE VARIABLE

X = AVAILABILITY BUDGET FACTOR

Table C-II

STATION / MISSION PHASE		PRE-LAUNCH	1ST & 2ND STAGE BOOST	EARTH ORBIT #1	EARTH ORBIT #2	EARTH ORBIT #3	INJECT TO TRANS-LUNAR	TRANS-LUNAR	LUNAR ORBIT & LANDING	LUNAR EXPLORATION	LUNAR LAUNCH	LUNAR ORBIT	INJECT TO TRANS-EARTH	TRANS-EARTH	RE-ENTRY	EARTH LANDING	RECOVERY	STATION AVAILABILITY
MISSION TIME (249.357 HOURS)		4	0.140	0.967	1.50	1.50	0.100	64.9	3.00	38.4	0.100	1.10	0.033	65.0	0.417	0.200	72.0	---
A CAPE CANAVERAL	R	(c) 22	(c) 22	(c) 22	(c) 22	(c) 22	(c) 22										(c) 22	(b) 454
	P	(f) 219	(f) 219	(f) 219	(f) 219	(f) 219	(f) 219										(f) 219	(e) 4533
B BERMUDA	R	(c) 53	(c) 53	(c) 69	(c) 53	(c) 53	(c) 53											(b) 734
	P	(f) 531	(f) 531	(f) 688	(f) 531	(f) 531	(f) 531											(e) 7344
C GRAND CANARY	R	(c) 53	(c) 22	(c) 69	(c) 53													(b) 797
	P	(f) 531	(f) 219	(f) 688	(f) 531													(e) 7969
D KANO	R	(c) 22		(c) 22	(c) 22		(c) 22											(b) 688
	P	(f) 219		(f) 219	(f) 219		(f) 219											(e) 6876
E JOHANNESBURG (DSIF)	R	(c) 22					(c) 22	(b) 891	(c) 06	(c) 06				(b) 891	(c) 22			(b) 360
	P	(f) 219					(f) 219	(e) 8906	(f) 062	(f) 062				(e) 8906	(f) 219			(e) 3593
F ZANZIBAR	R	(c) 22		(c) 22	(c) 22		(c) 22											
	P	(f) 219		(f) 219	(f) 219		(f) 219								(c) 22	(c) 22	(c) 22	(b) 454
G INDIAN OCEAN SHIP	R	(c) 53		(c) 53	(c) 53		(c) 38								(f) 219	(f) 219	(f) 219	(e) 4533
	P	(f) 531		(f) 531	(f) 531		(f) 375								(c) 53	(c) 53	(c) 53	(b) 656
H MUCHEA	R	(c) 06		(c) 53	(c) 53	(c) 38									(f) 531	(f) 531	(f) 531	(e) 6562
	P	(f) 062		(f) 531	(f) 531	(f) 375									(c) 53	(c) 53	(c) 53	(b) 609
I WOOMERA (REMOTE)	R	(c) 38		(c) 69	(c) 53		(c) 38								(f) 531	(f) 531	(f) 531	(e) 6093
	P	(f) 375		(f) 688	(f) 531		(f) 375								(c) 53	(c) 53	(c) 53	(b) 657
J WOOMERA (DSIF)	R	(c) 22						(b) 891	(c) 06	(b) 891				(b) 891	(f) 531	(f) 531	(f) 531	(e) 6563
	P	(f) 219						(e) 8906	(f) 062	(e) 8906				(e) 8906	(c) 22			(b) 532
K MINDINAO	R	(c) 53					(c) 53								(f) 219			(e) 5312
	P	(f) 531					(f) 531								(c) 53	(c) 53	(c) 53	(b) 765
L CANTON ISLAND	R	(c) 53		(c) 69	(c) 53	(c) 53	(c) 38								(f) 531	(f) 531	(f) 531	(e) 7656
	P	(f) 531		(f) 688	(f) 531	(f) 531	(f) 375								(c) 53	(c) 53	(c) 53	(b) 625
M KERMADEC ISLAND	R	(c) 06		(c) 22											(f) 531	(f) 531	(f) 531	(e) 6250
	P	(f) 062		(f) 219											(c) 38	(c) 38	(c) 38	(b) 642
N KAUAI ISLAND	R	(c) 53				(c) 53	(c) 53								(f) 375	(f) 375	(f) 375	(e) 6406
	P	(f) 531				(f) 531	(f) 531								(c) 53	(c) 53	(c) 53	(b) 718
O EASTER ISLAND	R	(c) 06													(f) 531	(f) 531	(f) 531	(e) 7187
	P	(f) 062													(c) 22	(c) 22	(c) 22	(b) 672
P PACIFIC OCEAN SHIP	R	(c) 53													(f) 219	(f) 219	(f) 219	(e) 6718
	P	(f) 531													(c) 53	(c) 53	(c) 53	(b) 812
Q POINT ARGUELLO	R	(c) 53			(c) 53	(c) 53									(f) 531	(f) 531	(f) 531	(e) 8125
	P	(f) 531			(f) 531	(f) 531									(c) 53	(c) 53	(c) 53	(b) 718
R GUAYMAS	R	(c) 06			(c) 38	(c) 38									(f) 531	(f) 531	(f) 531	(e) 7187
	P	(f) 062			(f) 375	(f) 375									(c) 38	(c) 38	(c) 38	(b) 596
S WHITE SANDS	R	(c) 22			(c) 22	(c) 22									(f) 375	(f) 375	(f) 375	(e) 5937
	P	(f) 219			(f) 219	(f) 219									(c) 22	(c) 22	(c) 22	(b) 531
T SAN ANTONIO	R	(c) 22			(c) 38	(c) 22									(f) 219	(f) 219	(f) 219	(e) 5314
	P	(f) 219			(f) 375	(f) 219									(c) 38	(c) 38	(c) 38	(b) 596
U HOUSTON (REMOTE)	R	(c) 22			(c) 38	(c) 38	(c) 22								(f) 375	(f) 375	(f) 375	(e) 5938
	P	(f) 219			(f) 375	(f) 375	(f) 219								(c) 38	(c) 38	(c) 38	(b) 534
V GOLDSTONE (DSIF)	R	(c) 22						(c) 69	(c) 22	(c) 53	(c) 69	(c) 53	(c) 84	(c) 53	(f) 375	(f) 375	(f) 375	(e) 5313
	P	(f) 219						(f) 688	(f) 219	(f) 531	(f) 688	(f) 531	(f) 844	(f) 531	(c) 22			(b) 547
W HOUSTON (MCC)	R	(c) 22	(c) 22	(c) 22	(c) 22	(c) 22	(c) 22	(c) 22	(c) 22	(c) 22	(c) 22	(c) 22	(c) 22	[c) 22	(f) 219			(e) 5469
	P	(f) 219	(f) 219	(f) 219	(f) 219	(f) 219	(f) 219	(f) 219	(f) 219	(f) 219	(f) 219	(f) 219	(f) 219	(f) 219	(c) 22	(c) 22	(c) 22	(a) 8752
X EGLIN	R	(c) 22			(c) 38	(c) 38									(f) 219	(f) 219	(f) 219	(c) 87585
	P	(f) 219			(f) 375	(f) 375										(c) 38	(c) 38	(b) 674
TOTAL PHASE AVAILABILITY	R	(a) 328	(b) 719	(b) 608	(b) 033	(b) 252	(b) 205	(b) 673	(b) 656	(b) 672	(b) 891	(b) 875	(b) 06	(b) 657	(a) 8830	(f) 375	(f) 375	(e) 6719
	P	(d) 83362	(e) 7188	(e) 3907	(e) 0312	(e) 2500	(e) 2032	(e) 6719	(e) 6562	(e) 6718	(e) 8907	(e) 8750	(f) 063	(e) 6562	(d) 88282	(b) 002	(a) 8924	.999
																(d) 89998	(d) 89219	.99999

R = STATION AVAILABILITY (RELIABILITY)

P = CREW SURVIVAL PROBABILITY

CELL CODE (a) = $.999 + (y \times 10^{-7})$ (d) = $.99999 + (y \times 10^{-10})$
(b) = $.9999 + (y \times 10^{-7})$ (e) = $.999999 + (y \times 10^{-10})$
(c) = $.99999 + (y \times 10^{-7})$ (f) = $.9999999 + (y \times 10^{-10})$

Table C-III